LEVEL II

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EAST-WEST TRADE AND POSTWAR SOVIET ECONOMIC GROWTH: A SECTORAL PRODUCTION FUNCTION APPROACH

9 Final rept.,

11 Jun[redacted]78

Technical Note
14 SSC-TN-2625-18

10 By: Steven Rosefielde

Contributors: Martin Weitzman
Donald W. Green

12 168 p.

Prepared for:

Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, Virginia 22209

15 Contract DAHC15-73-C-0380, ARPA Order-2520
ARPA Order No. 2520

SRI Project 2625

SRI International
1611 North Kent Street
Arlington, Virginia 22209

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SSC-TN-2625-18	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EAST-WEST TRADE AND POSTWAR SOVIET ECONOMIC GROWTH: A SECTORAL PRODUCTION FUNCTION APPROACH		5. TYPE OF REPORT & PERIOD COVERED Technical Note
		6. PERFORMING ORG. REPORT NUMBER N/A
7. AUTHOR(s) Steven Rosefielde Contributors: Martin Weitzman Donald W. Green		8. CONTRACT OR GRANT NUMBER(s) DAHC15-73-C-0380 ARPA Order No. 2520
9. PERFORMING ORGANIZATION NAME AND ADDRESS SRI-International, Strategic Studies Center, 1611 N. Kent Street, Arlington, VA 22209		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS SRI Project 2625
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, Virginia 22209		12. REPORT DATE June 1978 13. NO. OF PAGES 167
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office) Defense Supply Service-Washington Room 1D245, The Pentagon Washington, D.C. 20310		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report)

N/A

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Economics, Soviet Economy, Economic Growth, USSR

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical note includes an executive summary of the research effort, the main study of sectorial production function analysis of Soviet postwar economic growth, and a review paper.

The main study first sets out to calculate a probable upper limit to the contribution of technology transfer from the West to Soviet economic growth. The hypothesis is presented that this contribution is less than 2 billion dollars annually, unless the residual is strongly positively correlated with an appropriate measure of machinery imports from the West. In a series of estimations using

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (continued)

alternative labor income shares and measures of labor input, Solow Abramowitz residuals and Micks neutral technical progress residuals (from both CES and Cob-Douglass specificiations) are derived. These residuals are then correlated with patterns of imports of Western machinery, serially and cross-sectionally.

EXECUTIVE SUMMARY

Executive Summary

I BACKGROUND

As part of its National Security Policy Research Program sponsored by the Defense Advanced Research Projects Agency, SRI completed a study of the impact of technology transfer on technological change in the Soviet chemical industry.[1] That paper was in the nature of a pilot study of the value of econometric production function analysis for the examination of technical change and technology transfer in the Soviet context. The research was conducted in the face of numerous methodological, technical, and data problems but did furnish a number of interesting insights in regard to the high priority chemical sector. The rapid growth of chemical output was attributed primarily to increases of factor inputs, while the growth of the residual, as determined from the production function analysis, accounted for only between 6 and 10 percent of output growth. The comparable figure for the U.S. was about 20 percent of output growth due to the growth of the residual, one element of which is technical change.

Despite the problems encountered in that analysis, a further conclusion of the research was that work on an expanded set of branch production functions was warranted. The goal for the further research would be to derive a measure of the rate of technical change in each sector, by isolating to the extent possible technical change from other factors included in the residuals. This would permit branch-by-branch comparisons with the U.S. and other economies as well as a cross-sectional analysis to examine variance among branch rates of technical change and estimates of the relative importance of explanatory variables, including technology transfer from the West.

Thus at the outset of the study summarized in this report a number of statistical difficulties had been identified which would be necessary to allow for in the research approach. They included:

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[1] Carlisle Moody, Jr. and Francis W. Rushing, Technological Change in the Soviet Chemical Industry, SSC-TN-2625-8, Stanford Research Institute, February 1975.

- Aggregation problems, in some respects more troublesome at the branch level than industry-wide or economy-wide.
- Measurement of inputs--accurately capturing changes in quantity and quality.
- Measurement of output--accurately determining branch output while avoiding double-counting.
- Collinearity of capital, labor, and technical progress variables.
- Choosing between Cobb-Douglas and constant elasticity of substitution specification for production functions--a trade-off between the convenience of simplicity and statistical significance.
- Assumptions about elasticity of substitution and returns to scale, on the other hand, may bias the measure of technical change.
- Last, specification of the measure of technical change--that is the way in which technical change is assumed to be related to the arguments of the production function--in this case the residual (neutral and disembodied).

The main item of the research effort reported on here is the study undertaken by Dr. Stephen Rosefielde. Major technical reviewers were Dr. Donald W. Green and Dr. Martin L. Weitzman along with a number of other experts. While Dr. Rosefielde responded to many of the reviewers' comments on the first draft of his paper, it was not possible, within the time and resource constraints of the project, for him to incorporate all the suggested revisions still outstanding at the final stage, nor was there agreement among the author and reviewers on a number of those points. Some of those points will be covered in this Executive Summary. In addition, Dr. Weitzman authored a brief paper on his view of the research effort which appears together with the Rosefielde paper, and which raises important general issues in regard to the production function analysis of technical change.

II OUTLINE OF THE ROSEFIELDE STUDY

Rosefielde first sets out to calculate a probable upper limit to the contribution of technology transfer from the West to Soviet economic growth. Choosing 1973 as an example and employing a constant elasticity of substitution (CES) production function to estimate the residual and technical progress and

making a number of assumptions, the author formulates a hypothesis for the size of the Western contribution and a statistical test. The hypothesis is that technology transfer from the West contributes less than 2 billion dollars (.3 percent of GNP) annually to Soviet growth if the residual is not strongly, positively correlated with an appropriate measure of Western machinery imports. The rest of the study examines this hypothesis.

The author estimates Solow-Abramowitz residuals which assume a unitary elasticity of factor substitution and constant factor income shares across sectors. Income shares for labor of .80, .77, .73, and .68 as well as labor measured in man-years and also adjusted for man-hours worked are employed in a series of estimations. Output measures of two different forms, net output and final delivered output, and input measures to correspond (direct inputs of capital and labor and a new concept of direct plus indirect inputs which the author calls vertically integrated sectoring) were used. A number of alternatives are also used in the estimation of Hicks neutral technical progress residuals from CES and Cobb-Douglas production functions with linear and non-linear regression techniques, and the CES specification is deemed superior. The Abramowitz and CES productivity residuals are correlated with the pattern of Western machinery imports, serially and cross-sectionally.

III FINDINGS OF THE ROSEFIELDE STUDY

Though limited in their significance by substantial theoretical and statistical obstacles encountered in the analysis, the Rosefielde study does reach some conclusions in regard to the size of the contribution of technology transfer from the West to Soviet economic growth, the pattern of technological change at the branch level in postwar Soviet industry, and the correlation of technological change with a measure of technology transfer from the West. In light of the issues raised by a number of reviewers, the conclusions presented here ought not to be regarded as final answers, but rather as an indication of the types of insights that can be gained from the application of advanced econometric technique to the problem. The most important question that the sum of study findings and review comments should be directed to, then, is the advisability of further pursuing the analysis with this approach or some modification of the production function technique. This question will be addressed in the next section.

The conclusions of the Rosefielde study were as follows:

- The strong, positive correlation between some measure of technology transfer from the West and Soviet technical progress (estimated from production function analysis) that was hypothesized was not statistically validated.

- Thus the analysis would suggest that an annual contribution to Soviet economic growth by technology transfer from the West greater than 2 billion dollars is not plausible.

- Production function estimates using the Hicks neutral version of the CES specification were found to provide a more satisfactory characterization of Soviet industrial branch performance over the period than the Cobb-Douglas or Abramowitz alternatives. This finding was independent of the choice of sectoring schemes or the use of conventional or adjusted factor cost values.

- The CES specification portrays a moderate rate of Hicks neutral technical progress (about 3 percent) in postwar Soviet sectoral growth accompanied by rapidly declining income shares for capital. The implication is that future growth may be strongly linked to sustaining or enhancing rates of technical change, particularly in light of observed inelasticities of factor substitution.

- The inelasticities of factor substitution that are observed may result from the high institutional cost of designing flexible technologies in a bureaucratic economic system, i.e., if design flexibility (to account for changes in relative factor scarcities) is achieved only through additional material, engineering and bureaucratic costs, equipment may well be constructed with limited flexibility in the absence of market prices.

- A change in the aggregate composition of goods and services could potentially significantly affect the parameters of technology measured on an aggregate (industry-wide or economy-wide) basis. Even though the various branches of the Soviet economy have grown at diverse rates, postwar Soviet experience is not shown to be susceptible to this effect, since all sectors were characterized by low elasticity of factor substitution. The consistency of the findings across sectors not only suggests a small impact of structural change on the aggregate production specification, but also that there is a common underlying cause of inelastic factor substitution across branches.

- Some positive correlation between Western machinery imports (a measure of embodied technology transfer) and Hicks neutral technical progress is obsrved, but only after strategically grouping and aggregating annual data. The weakness of the correlation suggests that technology transfer from the West did not dominate the pattern of Soviet sectoral technical progress in the postwar period and that the annual contribution to Soviet economic growth is below the 2 billion dollar level.

- In the absence of a more sophisticated effort to determine the best specification of Soviet production, these findings should not be considered strong conclusions regarding the effect of technology transfer on Soviet technical progress.

IV IMPLICATIONS OF THE RESEARCH

Aside from unresolved methodological differences among the author and reviewers, two different views of the implications of the study findings for further research using advanced econometric approach emerged. On the one hand, some reviewers felt that the study demonstrated the data and specification problems which would prevent further resolution of the issues using currently available data and techniques. On the other hand, other reviewers maintained that some of the particular elements of the specific approach did not exhaust the analytical possibilities or were not the appropriate methodological formulation to provide answers to the key questions in the area, and thus additional research would be fruitful.

Some of the points made by Dr. Martin Weitzman supporting the first view include:

- From the evidence presented in the study, it seems that with existing data, the influence of technology transfer cannot be determined.
- A big part of the problem is that technical change, per se, is not very well understood.
- We cannot distinguish econometrically, with Soviet data, between the hypothesis of unitary elasticity of factor substitution (the Cobb-Douglas specification) with declining rates of technical change--or whatever is thought to determine the size of the residual--and the hypothesis of an elasticity of factor substitution sufficiently less than one with constant growth of the residual. Both hypotheses give a reasonably good fit for Soviet industry in the aggregate and by branch.
- The efficacy of correlating technical change estimates arising from these two very different pictures with imports of Western machinery and equipment that are generally very small in comparison with domestic investment is doubtful. Rosefielde's comparison reveals no systematic relationship, though its significance is limited by its rather informal execution.

- **Lastly, even if a positive correlation between imports of machinery from the West and technical progress (or the residual) were statistically validated, the causality would still be in question. It would be necessary to analyze some situations in which a relatively homogeneous subsector had received a significant portion of its capital stock from the West.**

In contrast to the pessimism expressed about resolving the issues econometrically based on the evidence in Rosefielde's study and elsewhere, other reviewers felt that while Rosefielde's particular efforts did not give definitive answers, alternative approaches could have more success. Major points in this line of argument included:

- Absolute rates of Hicks neutral technical progress need not be correlated with technology transfer activity. The real issue is whether growth of productivity in Soviet industry is statistically related to current and past accumulation of durables and importantly, the composition, by origin, of that accumulation.
- The hypothesis in the Rosefielde study is not given a specification which would in turn make that hypothesis testable.
- Two alternative approaches should be considered—the macro-approach which disaggregates capital stock by domestic and foreign origin or the introduction of technology transfer activity into the exponential term of the production function, imposing some appropriate lag distribution.[1]
- In Rosefielde's Cobb-Douglas functions, the inverse relationship between output elasticity of capital and the rate of Hicks-neutral technical progress was due to multicollinearity in the non-linear estimation of a linear function. While the CES specification was stated to be preferable, it was not tested by using earlier estimations to predict 1970-74 industrial growth.

While the Rosefielde study did not provide a generally acceptable answer to the question of the effect of technology transfer on postwar Soviet sectoral performance, the insights provided posed interesting questions for further research, and highlighted the critical aspects of any future methodological design. The key to the analysis in regard to these issues lies in the

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[1] See D. Green and M. Levine, Implications of Technology Transfer for the Soviet Union, SSC-TN-2970-8, Stanford Research Institute Technical Note, January 1977.

specification of technical progress and technology transfer. Thus, a high priority for further research to shed light on the value of technology transfer to the USSR and implications for East-West trade is the improvement of our understanding of the processes of technology transfer and technical progress themselves and the specific phenomena that embody these processes in the Soviet context. With this increased understanding, the ability to validate statistically quantitative hypotheses will be greatly improved.

ABSTRACT

This technical note includes an executive summary of the research effort, the main study of sectorial production function analysis of Soviet postwar economic growth, and a review paper.

The main study first sets out to calculate a probable upper limit to the contribution of technology transfer from the West to Soviet economic growth. The hypothesis is presented that this contribution is less than 2 billion dollars annually, unless the residual is strongly, positively correlated with an appropriate measure of machinery imports from the West. In a series of estimations using alternative labor income shares and measures of labor input, Solow Abramowitz residuals and Micks neutral technical progress residuals (from both CES and Cobb-Douglass specifications) are derived. These residuals are then correlated with patterns of imports of Western machinery, serially and cross-sectionally.

FOREWORD

The research effort reported on in this technical note was undertaken in light of recommendations of a pilot study on technical change in the Soviet chemical industry. Both that pilot study and this effort were a part of SRI's National Security Policy Research Program sponsored by the Defense Advanced Research Projects Agency. The pilot study concluded that despite numerous methodological, technical, and data problems, research on an expanded set of branch production functions in order to examine technical change and technology transfer in the Soviet context was warranted. While some of the problems encountered in the pilot study were not solved by this continued effort, the critical aspects of any future methodological design were highlighted and the insights provided posed interesting questions for further research.

Dr. Steven Rosefielde, of the University of North Carolina at Chapel Hill, served as principal investigator for the main study in the volume. Dr. Martin Weitzman of M.I.T. and Dr. Donald W. Green, then with the University of Pennsylvania and SRI, served as principal reviewers. Dr. Weitzman summarized his views in a brief research note which accompanies the main study in this volume. The views expressed by the author of the main study and by the reviewers are their own and do not reflect the positions of SRI and the Strategic Studies Center's Soviet and Comparative Economics research team.

Richard B. Foster
Senior Director
Strategic Studies Center

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EAST-WEST TRADE AND POSTWAR SOVIET ECONOMIC GROWTH: A SECTORAL PRODUCTION FUNCTION APPROACH

EAST-WEST TRADE AND POSTWAR SOVIET ECONOMIC GROWTH: A SECTORAL PRODUCTION FUNCTION APPROACH

INTRODUCTION

Over the last decade East-West trade has increased dramatically. From 1970 to 1974 the share of Western trade in total Soviet foreign trade turnover increased from 21% to 31%. It is frequently inferred from this and related statistical evidence that Detente has conferred sizable material benefits on the Soviets. While this inference is undoubtedly correct, the magnitude of the benefit remains unknown and poses a major problem for Western scholars concerned with the conseqeences of East-West trade.[1]

Measuring the gains obtained from international exchange is always difficult because the benefits of trade have no simple quantitative expression. Benefits are primarily derived from the average intramarginal "utility" advantage imports provide over exports sacrified, rather than from net commodity balances in the form of payment surpluses or deficits. As such they constitute a type of collective consumers' surplus, which suffers from all the ambiguities of individual consumer surplus, compounded by the problems associated with interpersonal utility aggregation.[2] Under Soviet conditions these difficulties become even more intractible because consumers' preferences do not determine relative prices, with the result that marginal utilities and prices are not correlated in the usual way. This is true for Soviet consumers at large and for the planners as well, and consequently accurate measurement of "utility" benefits from trade is infeasible.

Alternative conceptions of benefit are possible. One promising strategy is to transform the utility problem into a production or growth problem. Instead of focusing on traded goods as a whole, producers' durables can be singled out for special consideration. Unlike consumers' goods

producers' goods are employed in production and therefore have an impact on the volume and structure of real output. By treating this increment to real output as a measure of trade benefit, the concept of benefit can be interpreted physically, thereby allowing us to circumvent the imponderables of utility.[3] There is some loss entailed in this approach. Producers' goods are only a subset of all traded goods, however, an accurate partial measure seems better than no measure at all.

But can the real output increment attributable to imported producers' durables be accurately measured? A priori reflection provides no easy answer. The purpose of this pilot study therefore is to probe the feasibility of measuring trade gains in terms of domestic Soviet economic growth. In principle this objective can be accomplished by estimating the production function of each sector of the national economy before and after trade occurs, comparing outputs and sources of growth in both situations. If we had full information on the quality of Soviet imports and exports and various parameters of Soviet technology, calculation of trade benefits (the producers' goods component) would be relatively straightforward. Operating with less than full information matters are more complex causing problems both of theory and measurement. Since an appreciation of these problems is essential to any genuine understanding of Soviet trade gains, this paper attempts not only to report quantitative findings, but to set the entire issue in a clear analytic perspective. Towards this end, the study is divided into four parts. Chapter I introduces the notion of a production function, discusses problems of measurement and value, and special issues relevant to Soviet sectoral analysis. Chapter II focuses on technical progress, examining the sectoral pattern of Abramowitz residuals and their variation over time. Chapter III reports findings from a sector by sector estimation of the CES specification, while Chapter IV attempts a preliminary quantification of domestic Soviet gains from East-West trade.

Chapter I

PRODUCTION THEORY: PROBLEMS OF CONCEPTION AND MEASUREMENT

A. Production Functions

The laws governing the economic process of production where inputs are transformed into outputs can be expressed concisely in the form of a mathematical function. For every identifiable production process there will exist a corresponding "production" function. Since no single functional form can embrace the diverse types of production relations that hold in various firms and branches of the national economy, discussion is often facilitated by focusing on the general form

(1) $q = f(x,y,z)$

where q = output

x,y,z = inputs .

Equation 1 merely informs us that output q, is a function f, of inputs x,y,z. No restrictions are placed on q,x,y,z other than the simple requirements of intelligibility. Outputs and inputs must be positive; imaginary goods are barred, and all variables must be homogeneous in some accepted sense. The functional form f, is less self-apparent. It must embody all laws contributing to the process that transforms factors into goods. Included here as components of abstract technology are four basic elements:

1. the efficiency of technology
2. economies of scale
3. relative factor intensity
4. elasticity of factor substitution .

Technological efficiency denotes the output level that corresponds with any unit input level. If the other three properties of abstract technology are held ceteris paribus, output-input ratios which measure the efficiency of technology will vary with the state of technological development. As technology advances, output-input ratios rise as a result of more efficient production techniques.

Economies of scale also bear on output-input ratios but instead of referring to technical progress generally, they express efficiencies obtained from plant and market size. It is widely believed that optimal firm and market sizes exist for the production of different goods, and the more closely actual production scale approximates the ideal, the greater will be the corresponding level of output-input efficiency.

Relative factor intensity is a third and more subtle aspect of abstract technology. Under certain conditions (unitary elasticity of factor substitution) it merely describes whether more or less of either factor is employed in production compared with an alternative technology. Intensities here bear primarily on input-input rather than output-input relations. However, if either factor grows more rapidly than the other, the output level may be sensitive to the input mix, when the elasticity of factor substitution differs from unity.

The term elasticity of substitution, the fourth aspect of abstract technology, refers to the relative ease with which one factor can be substituted for another. More specifically it describes the rapidity with which diminishing returns set in to one factor when its relative price declines:

$$(2) \qquad \sigma \equiv \frac{[d(x/y)/(x/y)]}{[d(p_y/p_x)/(p_y/p_x)]} = \frac{[d(x/y)/d(p_y/p_x)]}{[(x/y)/(p_y/p_x)]}$$

Equivalently, interpreting relative prices as a ratio of marginal factor

productivities the elasticity of factor substitution can be construed more generally in terms of the effect variable factor supplies have on aggregate factor productivity given the technology embodied in the existing capital stock which indicates that the factor substitution elasticity concept is valid in either a market or planned economic setting.

$$\text{(2b)} \qquad \sigma = \frac{[d(x/y)/(x/y)]}{[d(f_y/f_x)/(f_y/f_x)]} = \frac{[d(x/y)/d(f_y/f_x)]}{[(x/y)/(f_y/f_x)]}$$

Algebraically σ, or the elasticity of substitution, represents the ratio of a marginal to an average function, where x and y are factors, and p_x, p_y their corresponding prices. The effect $d(x/y)$ of a relative price change $d(p_y/p_x)$ on the input volume x required to maintain the achieved output level may vary from zero to infinity, that is from absolute non-substitutability (σ=0) to perfect substitutes (σ=∞). In general the productivity of inputs is positively correlated with the elasticity of factor substitution. As σ increases, input combinations become possible requiring less of one factor, the other factor held fixed, indicating that more output can be obtained from any constant input bundle after the elasticity increases than before. Thus in terms of abstract technology σ has a direct effect on the output-input ratio. The elasticity of substitution as was previously noted also effects the output level indirectly through the "relative factor intensity" property. If σ is less than unity, diminishing returns will set in rapidly to the faster growing factor. The more intensively the prevailing technology utilizes the faster growing input, the greater the relative impact σ will have on output growth. If σ is greater, than one, this relationship is reversed. Clearly, the impact of the elasticity of substitution on output takes diverse forms, with the factor intensity effect either complimenting or offsetting variations in the value of σ on the output level.

B. Technological Change

Each of the four properties of abstract technology previously identified may either be independent or dependent on the activity level at which production occurs. The efficiency of production, returns to scale, factor intensity and elasticity of factor substitution observed at full capacity may well diverge from analogous values where lower utilization rates prevail.

Such variations should not be confused with technological change. The concept of steady state technology applies to the entire domain of production not just to the full capacity case. Whenever any characteristic of abstract technology at any activity level is altered by the introduction of a new process or a new condition of production, technological change is said to have occurred. The number of configurations of technological change over the entire domain of production is infinite. From a practical point of view however, attention need not be paid to every possible change in the structure of abstract technology. By convention a fundamental distinction can be made between the abstract technology associated with an initial capital stock which is assumed to hold unimpaired for a fixed period and the effect new inventions have on augmenting either factors or outputs. This distinction makes it unnecessary to perpetually revise the parameters of abstract technology as the capital stock is improved, so long as these improvements do not radically impair the validity of the initial functional specification. Of particular interest in this regard is the case of neutral technological change. Many definitions of neutral technical progress exist, the two most familiar being Hicks and Harrod neutrality. The former imputes all output growth other than that attributable to variations in input supplies to increased efficiency, leaving the marginal technical rate of factor substitution unchanged, if input proportions are fixed. Stated somewhat differently, under the assumption of Hicks neutrality the production function $f(x,y,z,t)$ holds unchanged for the time period under consideration, technical progress being reflected entirely in an efficiency growth residual $A(t)$, which augments the output level without affecting the production function itself. Notice that the invariance of the production function $f(x,y,z)$ does not preclude the possibility that

the marginal rate of technical substitution might vary.[4] If input proportions change the rate of substitution will be affected. This however is irrelevant because Hicks neutrality depends on new and old technologies having the same abstract character so that for any particular input ratio (such as the initial one) marginal technical rates of substitution will be identical.[5]

Harrod unlike Hicks neutral technical progress is especially concerned with the possibility that factor productivities and output elasticities may exhibit special intertemporal regularities, apart from preserving the parameters of abstract technology. In particular, Harrod assumes that the output elasticity of capital will remain constant over time. This implies that inventions are labor augmenting, as the capital stock increases relative to the labor supply. In the Harrod conception the average product of capital curve shifts iso-elastically as capital grows, assuming a constant rate of interest. Harrod's emphasis on the constant output elasticity of capital indicates his basic concern for the consequences of new innovations in altering the relative productivities that would have prevailed had capital growth been Hicks neutral. Neither the initial bundle of goods comprising output nor the initial marginal rate of technical substitution are especially important. What counts is the output-capital ratio and the intertemporal trend in the marginal product of labor.[6]

Neither Hicks nor Harrod neutrality is inherently superior to the other. Neutral technical progress could plausibly be of either type. Moreover, technological change need not be neutral. If it is, or closely approximates neutrality however, analysis is facilitated. If it is not, the exact nature of non-neutrality must be estimated through the use of diverse functional specifications.

The foregoing discussion has implicitly dealt with microeconomic production relations. It is common practice to disregard general equilibrium and treat the entire macro economy or specific sectors as if they constituted one gigantic firm. Aggregate production functions of this type are written in a form similar to equation (1),

(3) $Q = F(X,Y,Z,t)$.

More than time however is insinuated into the aggregate production function form. Output and inputs instead of representing homogeneous variables are necessarily heterogeneous. As output increases, its composition may change for reasons both of supply and demand. Such changes could easily be confused with technological progress adding further to the difficulty of actually measuring the components of abstract technology. In light of the foregoing discussion it should be clear that the complex reality of economic production, in a world of flux and technical progress, cannot be easily subsumed and measured in terms of a few simple characteristics of abstract technology. This acknowledgment however is not necessarily fatal. By judiciously employing the distinction between neutral and non-neutral technical change, by applying diverse statistical tests on alternative specifications, by assessing the systematic aspects of macro aggregative structural change, a workable model of the operative forces governing production can be devised. Such a model if understood as the best estimate it is, may serve useful analytic and policy functions, without implying more precision that its conceptual underpinnings can be made to plausibly bear.

C. Growth, Measurement and Technological Progress

1. The Effect of Qualitative Growth and Structure Change on Aggregate Production Relations

Suppose that production function analysis does provide us with a workable model of the aggregate production process. Is the knowledge it imparts

comprehensive and is it compatible with more traditional description of growth? The answer to this question depends on the fastidiousness with which production function estimation is executed. The issue involves problems both of conceptualization and measurement. Even at the level of the multiproduct firm, growth takes many forms. The first and most obvious is volumetric change, understood as variation in output and input magnitudes all treated as homogeneous goods. Qualitative change is a second and closely related aspect of growth in which the character as opposed to the volume of goods vary. Third, structural development alters the mix of inputs and outputs for broad classes of goods without affecting quality. Although there is a strong affinity among all three types of economic growth, production theory usually is preoccupied with volumetric change. As a result of this focus, growth, output-input ratios, and the form of the production function itself may be misestimated. the degree of error depending on the magnitude of qualitative and structural change.

In trying to appreciate what the omission of qualitative and structural growth might imply beyond simple misestimation, it is helpful to reflect once again on the problem of technological change. Suppose that technical progress estimated from deflated, but non-quality adjusted data is Hicks neutral so that the growth residual and the production function are separable. Can it be presumed that this separability will be preserved if input and output variables are redefined causing relative magnitudes and time trends to change? Can it be said that new inventions have the same abstract technological character as their predecessors so that for any given set of input proportions, the marginal rates of technical substitution will be identical? The answer depends largely on how seriously the analyst is committed to the conception of an aggregate production function.

If as a statement of faith one believes that the aggregate specification roughly approximates prevailing technology throughout the economy and all variables are homogeneous, qualitative change must be viewed as a spurious problem since with one good there can be only one quality. If this stance is relaxed and the heterogeneous character of outputs and inputs acknowledged, allowing for diverse sectoral technologies, Hicks separability is not sustained and must be reinterpreted. For it to be true that new and old inventions affect the marginal rate of technical substitution identically, input supplies impounded, the sectoral distribution of improved producers' durables must correspond with the initial distribution, otherwise weight of the technology specific to the expanding sector will increase relative to the average. Since quality growth and structural development mean precisely that fewer inferior goods are produced and the composition of outputs is altered in a preferred direction, the aggregate character of abstract technology will vary with technological progress and the condition that the marginal technical rate of substitution be the same for old and new capital stocks cannot be satisfied.[7]

Harrod neutral technical progress is also subverted by qualitative and structural change. The important point here though is not so much that a particular conception of neutrality is contingent on aggregate variables preserving a reasonable degree of intertemporal homogeneity, but that the very conception of an analytically valid aggregate production function depends on a substantial measure of stability in the heterogeneous composites designated as inputs and outputs. Under most circumstances we can hope that our aggregates are workably stable, however this hope should not be permitted to obscure the fact that during periods of radical structural transformation such as occurred in Soviet Russia 1928-1937 the necessary

stability minimum is probably lacking.[8] Instead of ignoring or suppressing the consequences of qualitative and structural growth, the analytic significance of these changes are assessed by measuring output series with alternative price weights, reflecting different tastes and/or technologies. This use of the conditional mood enables scholars to judiciously delineate coherent trends from empirical evidence which might otherwise appear to be completely ambiguous.

Traditional growth theory takes explicit cognizance of these difficulties and has elaborated an imposing body of doctrine centered around the concept of index number relativity. Although production theory has been less concerned with qualitative and structural growth than index number theory, the problem has been met indirectly through the concept of the technological epoch. As a working hypothesis it is conjectured that the parameters of abstract technology and the specific form of the aggregate production function remain in force for a discrete period. Technological progress within the epoch may be neutral or biased (capital or labor augmenting) so that change can be encompassed without having to adjust the parameters of abstract technology every time a new non-neutral invention enters the capital stock. So long as technical progress, biased or otherwise, and the qualitative and structural changes that follow in its train do not subvert the initial functional specification, the epoch is a useful construct. It can even be combined with index theory to provide additional insights when structural change is important, but not important enough to invalidate the meaning of a particular technological epoch. For example, suppose that technical progress is basically Hicks neutral, but the sector composition of final output is slowly changing and with it relative commodity prices. By employing a Lespeyres quantity index with base year price weights, Hicks neutrality takes on a conditional meaning with

reference to the initial output mix. As we saw earlier, neutrality of this sort is impure, but is nevertheless analytically useful. Harrod neutrality by contrast, with its emphasis on the output elasticity of capital and the rate of interest in years subsequent to the base year, could well be evaluated with moving end year price weights if the character of abstract technology after structural change had occurred seemed of interest. In epochs where structural change is potent therefore some decision on price weights is incumbent if a full apprecia-tion of the growth process is to be achieved. Even these devices however will be to no avail if structural change is really sizable, if the abstract technological character of the rapidly expanding sectors, alter the composite functional form in an appreciable way. Careful attention therefore must be paid to structural considerations before the findings of production function analysis can be given a definitive interpretation.

2. Sectoral Production Theory: The Role of Intermediate Inputs

Regardless of the prevailing epochal form, it may sometimes be useful to work with sectoral rather than aggregate production functions. This will be the preferred procedure whenever the technological structure of the macro economy is highly differentiated, or as in the foreign trade case, where the composition of imports diverges significantly from the export bill. Can we presume that sectoral production function analysis replicates aggregate

analysis in miniature? In one sense the answer to this question must be yes, for the specification of an aggregate relationship for a sector which subsumes the technologies of diverse firms without regard to their specificity differs from the macro aggregative approach in degree only. Both are statistical abstractions. Neither represents the production functions of particular firms. However, if attention is focused not on individual sectors in isolation, but on the entire environment of intersectoral relations the conceptual analogy between macro and sectoral aggregates degenerates. This degeneration reflects the endogenization of a fifth aspect of abstract technology not previously considered, the efficient utilization of intermediate inputs. Production of course entails the use both of intermediate and primary factors. The conventional specification of production processes however usually abstracts from intermediate inputs because according to marginal productivity theory intermediate inputs are produced goods whose price is determined by the marginal cost of primary factors employed elsewhere in the economy. Both micro and macro aggregative production functions therefore are represented net of intermediate inputs, as the physical analogue of a value added process.

This convention is justified at the level of the firm if technical progress is assumed to have no bearing on the utilization of intermediate inputs. It is also justified for the economy as a whole because all primary inputs are included as factors of production no matter how the structure of intermediate use varies over time. Sectoral aggregates however are embraced under neither of these headings. Input-output analysis has demonstrated that intermediate input technology is subject to substantial change at the sectoral level, while no individual sector, by analogy with the macro aggregate, employs the full primary factor stock. As a consequence, sectoral

production functions are best conceived in terms of the total set of relations governing output and inputs, within and among sectors. One way of accomplishing this objective without abandoning the conceptual framework of marginal productivity theory is to treat intermediate inputs as part of a broadened sectoral abstraction in which the primary factors utilized in the production of intermediate goods are classified with primary factors directly employed in the production process. Stretching the definition of sectoral production in this manner entails no theoretical costs, while providing substantial analytic benefits by incorporating all direct and indirect sources of sectoral technical change without omission. Conceptually it is equivalent to assuming that every sector is vertically integrated, producing all its own intermediate goods with diverse technologies from an initial endowment of primary factor inputs.[9]

Associated with this revised definition of sectoral production is the parallel requirement that qualitative changes (assuming no intrasectoral structure transformation) be attributed to the appropriate sectors of origin. Quality improvement can occur either in intermediate or final goods. Since our expanded definition encompasses both, they can be handled analogously. The correct method of adjustment for converting qualitative into quantitative growth depends on the character of the prevailing epoch. Base year relatives should be employed when Hicks neutrality seems plausible, other weights should be chosen for Harrod neutral or biased change as the analytical focus dictates.[10]

This same framework is relevant for variations in primary factor stocks as well. Where macro aggregate production functions are of concern it is often convenient to leave primary factor stocks unadjusted for quality changes that affect them in whole or in part, because they will be reflected

in the growth residual (or the efficiency parameter). The same procedure can be utilized for sectoral analysis, provided that the expanded definition of sector is employed. However the possibility always exists that qualitative changes in primary inputs may affect other aspects of abstract technology and if it appears that nonneutral effects of this kind might be concentrated in certain sectors, improved inputs can be converted into their equivalents of the old type using current year price weights.[11]

From the foregoing discussion it should be evident that the sectoral level of observation introduces a novel element into production theory; intersectoral relations or intermediate inputs. If conventional sectoral classification is preserved, the role of intermediate inputs will be obscured and true production relations misspecified. This difficulty however can be resolved by redefining sectors into vertically integrated entities, with the necessary quantitative recomputation carried out through an input-output algorithm.[12] Thus, if properly designed sectoral production function studies may not only be feasible, they may also be substantially superior to macro aggregative analysis where the underlying variables are intrinsically more heterogeneous than their sectoral counterparts.

3. Soviet Sectoral Production Analysis: The Problem of Administrative Prices

Most production studies of market economies start with the assumption that relative commodity prices are proportional to marginal costs, and relative factor prices are proportional to marginal productivities. No such presumption is admissible under Soviet conditions where prices are established according to certain bureaucratic accounting norms.[13] As a consequence, both input and output trends may be biased for all sectors, causing a fundamental misspecification of productive relations. Compounding this problem is the very real possibility that marginal factor productivities differ across

the sectors of the economy, implying persistent intersectoral disequilibrium. While no amount of adjustment is likely to resolve these problems in a definitive way, they can be greatly mitigated through an adjusted factor cost price correction derived from an input-output algorithm.[14] Conceptually such an adjustment has the effect of adding a scarcity charge for capital to all goods, and subtracting the direct and indirect distortionary influence of turnover taxes. It makes prices proportional to computed marginal costs (capital and labor), on the assumption that the observed structure of production reflects planners' marginal rates of transformation. To the extent that this is false, factor cost prices differ from their perfectly competitive analogues. However, if the underlying disequilibrium implied here remains more or less constant over time, adjusted factor cost valued inputs and outputs should provide a tolerable approximation to the variables desired in production function work. Thus although Soviet pricing poses serious problems for reliable production function analysis, the difficulties are not insuperable.

One further point is worth noting. Structural change in the Soviet economy is very systematic. Relative sectoral rates of growth are highly predicable. This suggests that technological progress could well be Hicks neutral. Should this prove to be the case, interpretation of the causal process of Soviet development would be greatly facilitated.

D. Econometrics Problems of Production Function Estimation: Identification

When two or more causal processes generate observationally equivalent structures, a fundamental problem of identification is encountered. Experience has shown that identification is a major and endemic problem in aggregate production function studies.[15] It is caused by a strong time trend in the dependent and independent variables, and by the large number of

parameters that typically need to be estimated. Observational errors further obfuscate matters. Moreover several plausible specifications, such as the constant elasticity of substitution form (CES) require the solution of equations which are nonlinear in their parameters. The algorithmic procedure employed to solve these nonlinear equations does not necessarily insure a global optimum. Depending on the initial values chosen for certain parameters, different local optima will be reached. Discovering the best fit may be a difficult task, especially if as has been recently emphasized, the underlying statistical distributions from which these estimates were generated is nonnormal.[16] Finally, as if the preceding encumbrances were not potent enough, available time series for each epoch often contain a relatively small number of observations, leaving few degrees of freedom for statistically meaningful assessment.

Taken together these debilities make it difficult to identify the best causal interpretation of prevailing production relations. Although a priori considerations could in principle assist us in resolving this impass, in practice there are too many plausible alternative causal processes for pure theory to be of much real help. Thus, while aggregate or sector production function theory is sufficiently comprehensible to allow meaningful testing, the fundamental econometric problem of identification often precludes an unambiguous appraisal of the causal laws governing production.

E. East-West Trade and Production Theory

In the preceding sections we discovered that production function analysis is part art and part science. Four basic conclusions follow from our discussion. First, if technical progress is roughly neutral so that the constituent elements of abstract technology remain relatively constant, despite qualitative and structural variations, measurement of the true causal process

becomes a conceptually feasible task. Second, sectoral production function studies are at least as reliable measures of true causality as aggregate production studies, if sectors are arranged into vertically integral units that endogenize intermediate inputs. Third, sectoral production function studies of the Soviet economy are feasible, and economically meaningful if all variables are computed in adjusted factor cost prices. Fourth, no matter how consistent the a priori design of a sectoral production function study, the fundamental econometric problem of identification must be faced and resolved in the most convincing manner feasible, even if a decisive resolution lies beyond our grasp.

Collectively these four conclusions imply that sectoral production function analysis can be meaningfully applied to Soviet data subject to the conventional limitations of the technique. The question then arises as to precisely how East-West trade fits into this framework. Net producers' durable imports alter the pattern of new capital formation in the various sectors of the national economy. If the volumes of investment durable transfers are sufficiently large they could make a perceptible difference in the achieved growth rates of each sector. This effect can be calculated first by adjusting the sectoral capital stocks, adding back exports and subtracting imports and second by adjusting output for these incremental changes in capital stocks.

Net producers' durable imports can effect the growth in another manner as well. If the technology embodied in imported durables is superior to that of exports, the average quality of the capital stock will rise. In principle this means that imported capital should be added to the sectoral stock at the domestic Soviet marginal rate of transformation appropriate to the epoch, with a direct adjustment for the productivity differential

made to those aspects of abstract technology affected by the technology transfer. Such an adjustment however is especially difficult because ex post data provides no independent observations on the form of pre transfer production function. Various expedients exist for circumventing this problem. The experience of sectors unaffected by trade transfers could serve as a referent for gauging the productivity increment associable with net investment durable imports. Or if the data neatly decomposed into pre trade and post trade epochs with sufficient observations in each period to make regression analysis statistically meaningful, the possible magnitude of the trade effect could be estimated. These are crude techniques which lump the effects of embodied and disembodied (scientific information, patents, blueprints etc.) transfers together, however they could suggest the order of magnitude of the efficiency benefit derived by the Soviets from foreign technology transfers as a whole.

Finally, another alternative might be considered. Direct sample comparisons of the relative efficiency of standard Soviet investors' durables and their imported counterparts could at the very least enable us to estimate the efficiency advantage of Western durables. Surrogates for such a sampling might also be found. If this information is taken in conjunction with a range of hypothetical diffusion rates the domain of feasible transfer benefits could be effectively delineated.[17]

In the following chapter we take a first step towards estimating the impact of East-West trade on Soviet sectoral growth by applying the traditional productivity residual method to compute the pattern and rate of productivity growth in the various sectors of the Soviet economy, using alternative weights and sectoral classifications. The data is of the unadjusted Lespeyres variety and is compatible with the Hicks neutrality assumption.

Introduction and Chapter I

Notes

1. I myself have argued this proposition. See Rosefielde, "Economic Development and the Changing Pattern of Soviet Foreign Trade," Current History, October 1975, 136-147.

2. For a complex attempt at measuring gains from trade see van Brabant, Bilateralism and Structural Bilateralism, Rotterdam University Press, 1973. On consumer surplus see Abram Bergson, "A Note on Consumer's Surplus," Journal of Economic Literature, Volume XIII, #1, March 1975, 38-44.

3. There is an implicit circularity in this argument since presumably the goods produced from imported durables are valuable only insofar as they will confer utility on those who will ultimately consume them. This difficulty can be partially obviated by appeal to the concept of production potential developed by Abram Bergson. So long as the normative ambiance of this standard is borne in mind, production potential or the growth increment serves a useful rough and ready measure of augmented physical capacity. See Abram Bergson, The Real National Income of Soviet Russia Since 1928, (Harvard University Press, Cambridge, 1961), 25-41 and Steven Rosefielde, "Sovietology and Index Number Theory," Economia Internazionale, February 1975, 42-53.

4. Consider the Cobb-Douglas case.

(1) $$Y = \gamma K^{\delta} L^{1-\delta} \quad .$$

The marginal products of capital and labor are

(2) $$\partial Y/\partial K = \delta\gamma K^{\delta-1} L^{1-\delta} = \delta\gamma K^{\delta} L^{1-\delta} (K^{-1}) = \delta Y/K$$

(3) $$\partial Y/\partial L = (1-\delta)\gamma K^{\delta} L^{(1-\delta)-1} = (1-\delta)\gamma K^{\delta} L^{(1-\delta)} (L^{-1}) = (1-\delta)\ Y/L$$

so that the marginal rate of technical substitution is

(4) $$\frac{\partial Y/\partial K}{\partial Y/\partial L} = \frac{\delta}{1-\delta} (L/K)$$

which clearly depends on the input proportions term L/K.

5. As we shall see shortly in the Soviet case, the marginal rate of technical substitution measured with a CES production function assuming Hicks neutral technical progress continuously declines in postwar period because capital inputs grow more rapidly than labor.

Equation one makes clear why this is so $\sigma > 0$

(1) $$\frac{\partial Y/\partial K}{\partial Y/\partial L} = \frac{\delta}{1-\delta}(L/K)^{1/\sigma} .$$

6. If the fixity of interest rate is insisted upon then it can be shown that Harrod neutral technical progress differs fundamentally from the Hicks specification because the marginal productivity of capital in the Hicks version is a function of time (t) as is evident in the CES example,

(1) $$\frac{\partial Y}{\partial K} = \delta e^{-\lambda\rho t}(Y/K)^{1-\sigma} .$$

See Charles Ferguson, The Neoclassical Theory of Production, (Cambridge University Press, Cambridge, 1969), 223-4. Also see Alberto Chilosi and Stanislaw Gomulka, "Technological Condition for Balanced Growth: A Critical Restatement," Journal of Economic Theory, Vol. 9, #2, October 1974, 171-184.

7. The seriousness of this problem depends in part on how different the underlying sectoral production functions are. For a terse and cogent discussion of the uniqueness of mean value functions see Ralph Pfouts and Cliff J. Huang, "A Production Function Generator," Revista Internazionale di Scienze Economiche e Commerciali, XXI, #2, 1974, 108-115. C.A. Knox Lovell, "A Note on Aggregation Bias and Loss," Journal of Econometrica, Vol. 1, #3, October 1973. Also Yasushi Toda, "Substitutability and Price Distortion in the Demand for Factors of Production: An Empirical Estimation." Paper presented at the American Economic Association Meetings, Dallas, December 1975.

8. This problem poses serious interpretational difficulties for some recent production function studies performed on data from the period of rapid Soviet industry. Since the technology of the diminishing light industrial and kustar sectors must surely have deviated drastically from the rapidly expanding steel, machinery and equipment sectors, further inquiry seems in order. See Barbara Katz, "Purges and Production: Soviet Economic Growth, 1928-1940," Journal of Economic History, September 1975.

9. Padma Desai, "The Production Function and Technical Change in Postwar Soviet Industry: A Re-examination," forthcoming.

10. The problem of quality adjusting inputs and outputs by sector pertains both to compositional changes in capital and labor. For example if the average educational level in the computer industry increases, aggregate labor must be adjusted within the sector, and if the quality of cars is improved through the purchase of better intermediate computer services, auto output must be revised upwards. Notice in this example that if the productivity pattern in both industries were treated separately, computer productivity would decline, auto productivity rise, when in fact all that had occurred was the numerical increase of one component of the labor aggregate.

11. A vintage calculation of the capital stock might be such an appropriate adjustment. Using one measure of capital a particular data set might appear to be best explained in terms of Hicks neutrality, using an alternative adjusted series Harrod neutral might seem best. Adjustments of this sort have affected the interpretation of postwar Soviet production. See Stanislaw Gomulka, "Soviet Postwar Industrial Growth, Capital-Labor Substitution and Technical changes: A Re-examination." Paper presented at BANFF, September 1974. Also it might be noted that much of Denison's approach to growth residual analysis takes the character of variable quality adjustment. See Edward Denison, Why Growth Rates Differ, (Brookings, Washington, D.C., 1967).

12. See Chapter II.

13. See Bergson, Real National Income of the Soviet Union Since 1928. Also Rosefielde and Lovell, "The Impact of Adjusted Factor Cost Valuation on the CES Interpretation of Postwar Soviet Economic Growth," unpublished manuscript.

14. Rosefielde, The Transformation of the 1966 Soviet Input-Output Table from Producers' to Adjusted Factor Cost Prices, (TEMPO, Washington, 1975), GE75TMP-47.

15. See Pfouts and Huang, "A Production Function Generator," Revista Internazionale di Scienze Economiche e Commerciali, XXI, #2, 1974, 114. Knox Lovell, "Technology and Specification Error," Southern Economic Journal, 40, 1973.

16. Theil, H., "The Analysis of Disturbances in Regression Analysis," Journal of the American Statistical Association, December 1965, 1067-79. Ramsey, J.B., "Test for Specification Errors in Classical Linear Least Squares Regression Analysis," Journal of the Royal Statistical Society, B, #2, 1969, 350-71. Ramsey and Zarembka, "Specification Error Tests and Alternative Functional Forms of the Aggregate Production Function," Journal of the Royal Statistical Association, September 1971, 471-77. Cliff Huang, "Normality of Disturbance Terms and Specification of the Production Functional Forms, Southern Economic Journal, 40, #1, July, 1973, 12-17. T. Krishna Kumar and James Gapinski, "Nonlinear Estimation of the CES Production Function: Sampling Distribution and Tests in Small Samples," Southern Economic Journal, 41, #2, October 1974, 258-266.

17. The literature on technological diffusion is large. Some recent contributions in the Soviet area include Stanislaw Gomulka and J.D. Sylwestiowicz, "Intercountry Embodied Diffusion and the Time Changes in the Factor Productivity Residual," in Altman, Kyn, Wagener (eds.), On the Measurement of Factor Productivities: Theoretical Problems and Practical Results, (Vandenhoek and Ruprecht), forthcoming. Donald Green and Marc Jarsulic, "Imported Machinery and Soviet Industrial Production, 1960-1973: An Econometric Analysis," Soviet Econometric Model Working Paper #39, September 1975.

Chapter II

THE SECTORAL PATTERN OF PRODUCTIVITY IN SOVIET INDUSTRY 1950-73

Given the analytical and econometric problems associated with production theory, it is often useful to assess the character of growth with simpler techniques. For example by studying the relationship between annual increases in output, capital and labor, growth can be divided into two components, one explained by the physical augmentation of primary input, the other by exogenous factors. The growth contribution ascribable to other causes is typically referred to as the "residual." Lumped together under the residual are improvements in labor skill, industrial organization, embodied technical change and returns to scale.[1] Although the residual is an amalgam precisely because its components cannot be easily separated according to their relative importance, a general picture of the range of feasible interpretations can be gleaned from a careful investigation of its behavior over time.

In the current economic literature two alternative measures of the productivity (growth) residual are frequently encountered. The Abramowitz residual is computed by subtracting a weighted measure of input growth from output growth:[2]

$$(1) \qquad R = \frac{dY}{Y} - \alpha\frac{dL}{L} - \beta\frac{dK}{K}$$

where R = residual

Y = income

L = labor

K = capital

α, β = income shares, labor and capital respectively.

The share of GNP contributed by labor (α) and capital (β) in the base period often are assumed to be proportional to marginal factor productivities. If Euler's Theorem holds moreover, then the underlying production function will be homogeneous, so that the residual implicitly contains non-specified growth sources, valued at their corresponding marginal productivities. Furthermore, since the integral of equation 1 can be derived from a Cobb-Douglas form, the Abramowitz residual presumes a unitary elasticity of substitution. Taken together, these properties impart a very definite meaning to the residual, which if not actually true, constitute a workable first step towards comprehensive assessment, especially so if the true underlying specification is unknown.[3]

The Solow Residual affords an alternative and more compressed expression:[4]

$$(2) \qquad \frac{dR/dt}{R} = \frac{(dY/dL)/dt}{Y/L} - \beta\frac{(dK/dL)/dt}{K/L}$$

or

$$(2a) \qquad \frac{\dot{R}}{R} = \frac{\dot{y}}{y} - \beta\frac{\dot{k}}{k}$$

where $\dot{R}$ = the time derivative of the residual

$\dot{y}$ = the time derivative of the output/labor ratio, interpreted as per worker output

$\dot{k}$ = the time derivative of the capital/labor ratio, interpreted as per worker capital input

β = the marginal product of capital.

It explicitly treats β not as an income share, but as the marginal product of capital.[5] Moreover, the Solow measure can be calculated from only one independent variable. This advantage however is not as great as it might appear and the Solow Residual can be expressed in the form of a total productivity index identical to equation 1.

Since the choice between these two residual measures depends on data availability and specification, in the analysis which follows we utilize the Abramowitz type residual which does not necessarily presume that income shares precisely correspond with marginal factor productivities. This choice however is of little importance because for the Soviet data assessed here, Abramowitz and Solow residuals seldom differ by 5% and never 25%.[6]

Although the Abramowitz specification given in equation 1 is quite simple, it nonetheless possesses several problems where sectoral production functions are concerned. How are we to interpret the variables themselves? How is labor to be measured? Should we treat capital and labor in any particular sector as the primary factors which give rise to sectoral output, or should we rather compute the direct-plus-indirect factor requirements needed to sustain sectoral production from whatever sector they are obtained? Likewise how should the coefficients be treated? Factor shares are not invariant to the price system, nor to accounting conventions. Should Soviet measures of profit be taken seriously? What about interest? Can prices be adjusted?

All these issues are important, and therefore rather than preclude various alternatives for one reason or another the following expedients were adopted. First, factor input was measured both directly in terms of the sector of ownership or control and directly-plus-indirectly by sector of origin. Second, labor was computed both in man years, and in man years adjusted for changes in man hours. Third, various alternative income share measures were applied as parametric weights in calculating the residual. More specifically, two distinct production schemes were considered. The first is derived from the conventional specification which relates gross sectoral output to sectoral input:

(3) $$Y_i = RF(K_i, L_i) \quad .$$

Instead however of correlating gross output and input series, a net product measure is utilized for Y_i which excludes intermediate inputs.

The second specification is a value-added flow form

(4) $Y_i = RF(K_j, L_j)$ $j=1,\dots i,\dots n$

where $Y_i = \sum_{j=1}^{n} Y_j$, the output of sector i equals the value added contributed by all j sectors including the i th

K_j = all the direct-plus-indirect capital required to deliver Y_i to final demand

L_j = all the direct-plus-indirect labor required to deliver Y_i to final demand.

Since the rational behind these alternative formulations may not be fully understood, let us pause to reflect on their meaning before proceeding to explain computational fine points. The central problem with conventional sectoring is that it is inconsistent with national income accounting theory and practice. Gross national product is always equal to total factor cost including profit. By analogy the final product of every sector should be related to the factors required for its production. If sectors were completely independent of each other, this condition would be easily satisfied. But ordinarily a certain share of the output of one sector instead of being delivered directly to final consumption is employed as an intermediate input for the production of goods in some other sector. These intermediate inputs become an integral part of the final product of the purchasing sector. For example tires are essential to automobiles, even though they might be classified technically as the product of the rubber industry. Their cost is included in the price of the final good, and is presumably equal to the value added by the factors employed in the production of these

intermediate inputs. From the viewpoint of conventional production function analysis however intermediate inputs are treated inconsistently. Using gross value of output sectoral series, intermediate inputs are subsumed as a component of cost and therefore output, but the factors associated with their production are excluded from the input series. As a consequence, reported output far exceeds the quantity of factors required to sustain implied activity levels. Moreover, if the relationship between final output and intermediate input varies intertemporally the parameters of abstract technology might be misestimated on this account. Thus the use of gross output series not only misrepresents the production process, it runs the risk of misconstruing changes in the level of intermediate input intensity with changes in technology more narrowly defined.

In principle two alternative procedures are available to deal with the problem of intermediate goods. Both permit consistent sectoring, but differ conceptually. The first and simplest approach (equation 3) merely subtracts intermediate inputs, including internally produced intermediate goods from gross sectoral output. The resulting net output series is thereby rendered consistent with factors classified by origin, but has a very distinct meaning. Returning to the automobile example alluded to above, the product of the automotive sector is the assembled chaisse, the assembled motor, the installed textiles, and products of the petrochemical industry, including tires, the steering wheel and dashboard. The unassembled intermediate materials themselves are excluded from net product. Now insofar as any particular analysis calls for the investigation of technical progress in the automotive <u>assembling</u> industry, the net output approach constitutes the appropriate nomenclature convention. Ofter however one might suppose our interest inheres not in assembling per se, but in the total technology

that governs the production of automobiles. Intermediate inputs in this view rather than being treated as alien goods are conceived of as an essential part of a vertically integrated production process, each component of which contributes to the total opportunity cost of output.

The advantage of a vertically integrated sectoral nomenclature is that it conforms with commonsense and the national income accounting notion of a product as a final delivered good instead of the abstraction "value of assemblage." Its disadvantages are threefold. It is difficult to compute, it is unfamiliar, and it appears to diverge from some implicit engineering ideal of a sector as a discrete abstract process. The first two problems are not really substantive in the final analysis. The third deserves more detailed consideration. By analogy with the theory of the firm, it is possible to imagine a production function as an expression of engineering norms for a specific production technique. It is tempting to extrapolate this imagery to aggregate sectors such as chemicals, machine building, metals etc., but this could only be apposite in a very loose sense. A large component of factor use in any sector is necessarily comprised of non-assembly line work, and the relationship of capital and labor to output where a large and variable array of specific intrasectoral production techniques are aggregated is anything but precisely correlated with some discrete notion of engineering technique. Concretely then the choice between the net output and vertically integrated nomenclature conventions hinges fundamentally on whether the analyst is concerned with assemblage technology or delivered final product. In this chapter statistical material is presented for both sectoral classifications, but it is the author's view that the vertical integration nomenclature is the more interesting. Before proceeding to an evaluation of these findings,

let us see more exactly how vertically integrated output and input series can be computed from input-output data.

The logic of the transformation from independent to vertically integrated sectoring requires that the output of all industries be calculated in terms of final delivered product, and that the inputs actually required to sustain that product be recorded irrespective of their sector of origin. The first condition has been met pro forma by extrapolating the ratio of final to gross sectoral output forward and backwards from the 1966 Soviet input-output table. The same net-gross assumption is employed in transforming the conventional direct sectoral specification of equation 3 into the appropriate net product form. The second condition is satisfied by computing all direct-plus-indirect factors needed for the production of the intermediate inputs embodied in final output, including the value added of the producing sector.

Various methods exist for computing direct-plus-indirect flows. One intuitive approach is to rearrange the flows of the input-output table so that the final output of each sector is included in each a_{ii} cell, making it possible to associate capital and labor in the originating sector with the physical output level (intermediate and final) in the same sector of origin. For example the standard I-O equational system

$$
\text{(5a)}\quad
\begin{array}{ccccccc}
a_{11}X_1 + a_{12}X_2 & \cdots & a_{1n}X_n & + & C_1 & = & X_1 \\
a_{21}X_1 + a_{22}X_2 & \cdots & a_{2n}X_n & + & C_2 & = & X_2 \\
\vdots \qquad \vdots & & & & \vdots & & \vdots \\
a_{n1}X_1 + a_{n2}X_2 & \cdots & a_{nn}X_n & + & C_n & = & X_n
\end{array}
$$

can be rewritten as:

$$
\begin{array}{lllll}
\text{(5b)} & a_{11}X_1 + C_1 & a_{12}X_2 & \cdots\ a_{1n}X_n & = X_1 \\
 & a_{21}X_1 & a_{22}X_2 + C_2 & \cdots\ a_{2n}X_n & = X_2 \\
 & \vdots & \vdots & \vdots & \vdots \\
 & a_{n1}X_1 & a_{n2}X_2 & \cdots\ a_{nn}X_n + C_n & = X_n
\end{array}
$$

or redefining X_i and a_{ii} as $X_i^* = X_i + C_i$, and $a_{ii}^* = (x_{ii} + C_i)/(X_i + C_i)$.

(5c) $$X^* = A^* X^*$$

$$
= \begin{bmatrix} a_{11}^* X_1 + C_1 & a_{11}X_2 \\ a_{21}X_2 & a_{22}^* X_2 + C_2 \end{bmatrix} = \begin{bmatrix} X_{11}^* & X_{12} \\ X_{21} & X_{22}^* \end{bmatrix}
$$

where

X^* = gross flows

A^* = the technology matrix

C = a vector of final outputs .

Dropping the asterisks for notational simplicity, the resulting gross output flow matrix is next converted into a labor and capital flow matrix by pre-multiplying the output flow matrix with the appropriate diagonal labor/output and capital/output ratios:

$$(6) \qquad K = \begin{bmatrix} K_1/X_1 & 0 \\ 0 & K_2/X_2 \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix}$$

$$= \begin{bmatrix} (K_1/X_1)X_{11} & (K_1/X_1)X_{12} \\ (K_2/X_2)X_{21} & (K_2/X_2)X_{22} \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

$$(7) \qquad L = \begin{bmatrix} L_1/X_1 & 0 \\ 0 & L_2/X_2 \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix}$$

$$= \begin{bmatrix} (L_1/X_1)X_{11} & (L_1/X_1)X_{12} \\ (L_2/X_2)X_{21} & (L_2/X_2)X_{22} \end{bmatrix} = \begin{bmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{bmatrix}$$

Then premultiplying (6) and (7) by a row sum vector of ones, yields the desired measures of direct-plus-indirect capital and labor required to produce observed gross output of each sector.

$$(8) \qquad \lambda = eL$$

$$= [1 \ 1] \begin{bmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{bmatrix} = [L_{11} + L_{21} \quad L_{12} + L_{22}]$$

$$(9) \qquad \kappa = eK$$

$$= [1 \ 1] \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} = [K_{11} + K_{21} \quad K_{12} + K_{22}]$$

Since we are dealing with serial data λ and κ must be serially adjusted. A full adjustment would entail the use of a series of input-output tables that accounted for all technical changes. Lacking the necessary tables, as a

second best we presume that the technology matrix remains unaltered, varying the volume of capital and labor annually with indices of factor growth. This allows the differential rates of sectoral factor accumulation to express themselves in the flow of primary factor matrices, assuming a stable structure of intersectoral demand. Equations 10 and 11 illustrate the computational process, where each partition of the primary factor flow matrix corresponds to a particular year during the period 1950-1973, and the matrices $(I+\Gamma)$ and $(I+\Omega)$ are arrays of capital and labor growth indices, respectively.

$$(10) \qquad K^{*} = (I+\Gamma)K$$

$$= \left[\begin{array}{cc|cc|c|cc} (1+\gamma_1^1) & 0 & (1+\gamma_1^2) & 0 & & (1+\gamma_1^{24}) & 0 \\ 0 & (1+\gamma_2^1) & 0 & (1+\gamma_2^2) & \cdots & 0 & (1+\gamma_2^{24}) \end{array}\right]$$

$$\left[\begin{array}{cc|cc|c|cc} K_{11}^1 & K_{12}^1 & K_{11}^2 & K_{12}^2 & & K_{11}^{24} & K_{12}^{24} \\ K_{21}^1 & K_{22}^1 & K_{21}^2 & K_{22}^2 & \cdots & K_{21}^{24} & K_{22}^{24} \end{array}\right]$$

$$= \left[\begin{array}{cc|c|cc} (1+\gamma_1^1)K_{11}^1 & (1+\gamma_1^1)K_{12}^1 & & (1+\gamma_1^{23})K_{11}^{24} & (1+\gamma_1^{23})K_{12}^{24} \\ (1+\gamma_2^1)K_{21}^1 & (1+\gamma_2^1)K_{22}^1 & \cdots & (1+\gamma_2^{23})K_{21}^{24} & (1+\gamma_2^{23})K_{22}^{24} \end{array}\right]$$

$$(11) \qquad L^{*} = (I+\Omega)L$$

$$= \left[\begin{array}{cc|cc|c|cc} (1+\omega_1^1) & 0 & (1+\omega_1^2) & 0 & & (1+\omega_1^{24}) & 0 \\ 0 & (1+\omega_2^1) & 0 & (1+\omega_2^2) & \cdots & 0 & (1+\omega_2^{24} \end{array}\right]$$

$$\left[\begin{array}{cc|cc|c|cc} L_{11}^1 & L_{12}^1 & L_{11}^2 & L_{12}^2 & & L_{11}^{24} & L_{12}^{24} \\ L_{21}^1 & L_{22}^1 & L_{21}^2 & L_{22}^2 & \cdots & L_{21}^{24} & L_{22}^{24} \end{array}\right]$$

$$= \left[\begin{array}{cc|c|cc} (1+\omega_1^1)L_{11}^1 & (1+\omega_1^1)L_{12}^1 & & (1+\omega_1^{24})L_{11}^{24} & (1+\omega_1^{24})L_{12}^{24} \\ & & \cdots & & \\ (1+\omega_2^1)L_{21}^1 & (1+\omega_2^1)L_{22}^1 & & (1+\omega_2^{24})L_{21}^{24} & (1+\omega_2^{24})L_{22}^{24} \end{array}\right]$$

Premultiplying equations 10 and 11 by a sum vector of ones provides us with a 1 x 24 partitioned array of direct-plus-indirect sectoral factor inputs, representing a time series of factor supply.

(12) $\kappa = eK^*$

(13) $\Lambda = eL^*$

where κ = a 1 x 48 partitioned vector of capital inputs, 1950-1974

K^* = a 2 x 48 partitioned vector of capital flows, 1950-1974

Λ = a 1 x 48 partitioned vector of labor inputs, 1950-1974

L^* = a 2 x 48 partitioned vector of labor flows, 1950-1974

e = a 1 x 48 partitioned sum vector of ones.

While the assumption of constant intersectoral flow structure is certainly unsatisfactory for a detailed sectoral breakdown, it is probably workable for the large aggregates employed here. Moreover, it should be clearly borne in mind that the factor flow transformations do not actually add a new source of distortion to the measurement of the residual. Changes in intersectoral flows are real, and the conventional gross output, gross input approach rather than avoiding this difficulty merely covers it up. Thus in choosing between equations 3 and 4, what counts is not the technique used to compute direct-plus-indirect input flows, but the plausibility of the basic specifications. Note also the logic of the transformation. Final output is added to the diagonal elements of the intersectoral flow matrix because the capital-output ratio for each sector refers to gross output including final consumption. Each diagonal element therefore represents gross sectoral

output which is then converted into own sector capital or labor. The summation down each column therefore tells us the primary input value of intermediate and final goods, in terms of the capital and labor directly embodied from each originating sector. This method is equivalent to holding intersectoral relations constant, while adjusting the primary input-output ratios for changes in productivity. Since the volume and structure of both inputs and outputs vary serially, the assumption of a constant technology matrix cannot be taken too literally, and for this reason direct-plus-indirect primary input requirements have not been computed formally through the inverse method, even though equations 5-13 are precisely equivalent to the inverse procedure where the primary input-output ratios are adjusted serially, but the inverse is left unaltered. In a nutshell then, whenever the focus of analysis shifts from a few aggregate variables to the interindustry context in which they are embedded, implicit assumptions of some dubiousness are bared which might otherwise not meet the light of day.

Turning our attention from the nomenclature problem explored above, it must be recognized that the choice of variables affects the computational value of the residual. In the first section of this paper we explored the theoretical aspect of this problem. Concern here centers on a more pragmatic choice. Should labor be measured in man years or man hours? Selection of the former alternative implies that output is independent of the length of the workweek; selection of the latter assumes that output varies proportionally with man hour input. Denison has suggested that both assumptions are correct over different ranges of the feasible workweek. For workweeks in excess of 48 hours, a decline in worktime has no effect on output. For workweeks less than 34 hours, the relationship is one to one. The middle range is not entirely symmetric with productivity loses increasing

more rapidly after the 40 hour workweek is achieved. If Denison is approximately correct this implies that since the Soviet workweek 1950-1973 contracted roughly from 48 to 40 hours the average decline in "standard productivity" labor input was about 20% of the reduction or 3% in all ((Δ8 hours/48 hours) x .2 = 3.33%).[7] Soviet conditions, of course, might not correspond with those of the developed West, and for this reason we present two variants of the residual, one in average man years, the other in average man years adjusted for changes in average man hours. The Denison productivity adjustment is <u>not</u> applied, but can easily be computed through interpolation, thereby leaving the choice of the "true" labor input measure to the reader.

Finally, the issue of income share weights must be addressed. In principle the appeal of income share weight reposes in the possibility that factor shares might be proportional to marginal productivities. In a market context, as Denison points out such a supposition is at least plausible.[8] In the Soviet Union however, where labor value accounting prices are employed it cannot be persuasively argued that income shares are proportional to marginal productivities. Judith Thorton's calculations are instructive in this regard indicating a fall in labor's share 1955-1967 from 68% to 47% of income.[9] There is no Western precedent for such shares. Even in Japan, labor's share is 69%.[10] The separation between shares and productivities moreover makes unlikely that the simple computation of any particular share will be proportional to productivities. Recourse therefore must be taken to computing the Abramowitz residual with a range of income share weights to gauge the effect of alternative values. Four sets weights were chosen for this purpose: w = .80, .77, .73, .68, where w is the labor share. These values correspond respectively to 1) the American share 2) labor's

share taken from the 1966 Soviet I-O table measured in producers' prices 3) labor's share taken from the same table in 6% adjusted factor cost prices and 4) labor's share again from the 1966 table evaluated in 12% adjusted factor cost prices.[11] The 6% and 12% figures used in variants 3 and 4 designate the rates of interest (capital services) applied in revaluing the table. Certain coincidences should also be noted. Variant 2 was utilized by Bergson in his recent productivity study, while Variant 4 corresponds closely with the Japanese income share value. Thus each set of weights arbitrary as they are, possess clear referents that make them comparable with other studies. In the statistics that follow, it will be apparent that all sectors are evaluated together with the same income share weights. If factors in the Soviet Union earned the value of their marginal products this would pose no problem. Since this is not the case it is possible that underlying marginal productivities could vary sectorally. The author has no way of ascertaining whether systematic deviations from the economywide marginal productivity standard occurs in the Soviet Union, but should the reader have some good hunches data is supplied which should permit him to make the necessary adjustments.[12]

Having described the various conventions employed in the computation of the Abramowitz residual, let us consider the empirical results.[13] Tables 1-3 present average Abramowitz residuals for seven aggregate sectors and total industry, excluding construction, trade, transportation and communications.[14] The top panel of each table provides residual statistics computed from direct factor use (1) and direct-plus-indirect factor use (2), along with corresponding figures for labor measured in average man years (A) and average man years adjusted for changes in man hours (B). The lower panel calculates the effect direct-plus-indirect factor use has on sectoral

residuals compared with the direct factor use standard. Each of these tables therefore provide the same information, except for the labor income share which is allowed to vary.

Inspection of Table 1 based on American income share weights ($w = .80$) immediately reveals that the Abramowitz residual is quite sensitive to whether direct or direct-plus-indirect income shares are employed. Two effects are discernible. First, the dispersion of residual values approximately doubles, and second the ordering of the sectors is rearranged. In particular, the relative performances of the chemical and the machinery and equipment rise dramatically, while fuels, metals and construction materials deteriorate. The order of the food and light industrial sector remain unchanged at the bottom of the residual listing. Table 1b sheds additional light on this process. Chemicals and machinery and equipment residuals increase substantially above average while fuels, construction materials, metals, light industry and food decline in that order. With the exception of construction materials, the same pattern holds regardless of how labor input is measured. The extraordinary behavior of construction materials is attributable to an increase in the average workweek in the timber and paper sector (aggregated into conmat), whereas the workweek declined generally elsewhere. Also as can be seen without difficulty, the use of man hour adjusted labor increases the average (industrial) Abramowitz residual 20% for the direct, and 17% for the direct-plus-indirect factor measure. Accepting Denison's statistical evidence this implies that the interpolated difference is only 3% to 4% which is not significant enough to command our attention. Only if the full decline in labor hours corresponds with a proportional fall in output does the adjustment become really important. Clearly then the most salient aspects of the Abramowitz residuals in Table 1

are their overall magnitude on the order of 3%, and the dispersionary effect of utilizing factor inputs measured directly-plus-indirectly which convert the chemical and machinery and equipment sectors from sluggish to rapid technology intensive growth nodes of the national economy.

Tables 2 and 3 tell much the same story. However, as the capital share rises, the productivity residual declines. This phenomenon reflects the fact that annual capital stock growth is more rapid than labor growth, so that the higher β, the greater the net subtraction from unexplained output growth $(-\beta\frac{dK}{K})$. Using the industry average as the bench mark, a 60% increase in capital's share from .20 to .32, diminishes the residual approximately 27%. Technical progress instead of averaging 3% per annum averages closer to 2% using 12% adjusted factor cost income share weights. This effect is clearly greater than the choice of factor input measure or the specification of the labor variable. Moreover, its impact on the dispersion between Abramowitz residuals computed from direct as opposed to direct-plus-indirect factor inputs is marked. Whereas the range separating the chemical from the light industrial residual was 2 to 1 in Table 1b, column A, it is 3 to 1 in Table 3b, column A. This suggests that if adjusted factor cost values really do reflect scarcity relatives better than producers' values, the pattern of sector productivity growth in the Soviet Union is substantially masked by conventional use of direct factor inputs and producers' income shares. The differences in magnitude entailed are significant and will certainly affect any appraisal of relative Soviet performance. Table 4 which compares the conventional measure using Bergson weights and the 12% adjusted factor cost variant, computed from direct-plus-indirect factor inputs with labor adjusted for changes in man hours, subject to the Denison correction, makes this point manifest. On one view, there is little sector differentiation in productivity residuals with technological progress

centered in the non-agrarian primary products industries; on the other technological progress is unevenly distributed among the sectors, with the tertiary goods sector serving as the leading edge of growth.

This impression is enriched by considering Tables 5-13 where the Abramowitz residuals are arrayed according to an historical periodization suggested by Donald Green, instead of the 24 year averages reported above. (Similar tables based on simple five year averages are also provided in Appendix A2.1.) Consider Table 5 in particular, which contrasts the vertically integrated with the conventional sectoring, valued in adjusted factor cost and producers' prices respectively. Notice first that the rate of residual growth has not been constant over time. Looking at industry as a whole a u-shaped pattern is discernible with a trough in the period 1959-63, followed by a recovery 1968-73 to approximately 62% of the 1950-58 level. The industry average however disguises some important sub-trends. On an adjusted factor cost basis the chemical residual is constant throughout, vertically integrated but u-shaped on the narrower direct input measure. Metals decline generally on a vertically integrated adjusted factor cost basis, while the light and food industries follow an erratic course. On the whole the conventional measure exhibits the u-shaped pattern whereas the behavior of the vertically integrated adjusted factor cost residuals are more diverse. Clearly, residual studies employing these alternative measures will produce divergent interpretations of the pattern of Soviet technological progress, each with their own special analytic meaning.

The nomenclature issue aside, however, two general points of interest are discernible for all measures. First, the Soviets have managed to shore up flagging technological progress during the Brezhnev years. Second, since

growth rates tended to decline modestly during this period the declines are attributable to reduced rates of primary factor input growth. It is interesting to speculate whether these phenomena might be interrelated. For the moment however, the reader is urged to peruse Table 6-13 (and summary Table A2-1 in Appendix A2.1 based on standardized five year time periods), which afford additional insights into the residual problem before we proceed to an assessment of the relative importance of various elements within the residual itself.

TABLE 1a

Abramowitz Residuals (w = .80)
1950-1973 Average

	Direct Factor Use (1)				Direct Plus Indirect Factor Use (2)		
		A	B			A	B
1.	Fuels	3.46	4.05	1.	Chemistry	4.80	5.39
2.	Metals	3.26	3.87	2.	Machinery and Equipment	3.57	4.17
3.	Conmat	3.06	3.50	3.	Fuels	3.26	3.86
4.	Machinery and Equipment	3.00	3.59	4.	Industry	2.95	3.53
5.	Industry	2.89	3.48	5.	Metals	2.80	3.41
6.	Chemistry	2.85	3.44	6.	Conmat	2.71	3.25
7.	Food	2.77	3.18	7.	Food	2.19	2.69
8.	Light	2.49	3.06	8.	Light	2.04	2.62

A = Abramowitz Residual: labor in man years

B = Abramawitz Residual: labor in man years adjusted for changes in man hours.

TABLE 1b

Effect of the Full Factor Input Measure
On Abramowitz Residuals: w = .80
(Column 2/Column 1)

	SECTOR	A	B
1.	Chemistry	1.68	1.56
2.	Machinery and Equipment	1.19	1.16
3.	Industry	1.02	1.01
4.	Fuels	0.94	0.95
5.	Conmat	0.89	0.93
6.	Metals	0.86	0.88
7.	Light	0.82	0.85
8.	Food	0.79	0.86

TABLE 2a

Abramowitz Residuals (w = .77)
1950-1973 Average

	Direct Factor Use (1)			Direct Plus Indirect Factor Use (2)	
	A	B		A	B
1. Fuels	3.25	3.82	1. Chemistry	4.58	5.16
2. Metals	3.03	3.61	2. Machinery and Equipment	3.40	3.97
3. Machinery and Equipment	2.87	3.44	3. Fuels	3.05	3.63
4. Conmat	2.83	3.25	4. Industry	2.75	3.31
5. Industry	2.69	3.26	5. Metals	2.59	3.17
6. Chemistry	2.61	3.18	6. Conmat	2.49	3.01
7. Food	2.57	2.96	7. Food	1.99	2.47
8. Light	2.29	2.85	8. Light	1.84	2.40

A = Abramowitz Residual: labor in man years

B = Abramowitz Residual: labor in man years, adjusted for changes in man hours

TABLE 2b

Effect of Full Factor Input Measure
On Abramowitz Residuals (w = .77)
(Column 2/Column 1)

SECTOR	A	B
1. Chemistry	1.75	1.62
2. Machninery and Equipment	1.18	1.15
3. Industry	1.02	1.02
4. Fuels	0.94	0.95
5. Conmat	0.88	0.93
6. Metals	0.85	0.88
7. Light	0.80	0.84
8. Food	0.77	0.83

TABLE 3a

Abramowitz Residuals (w = .68)
1950-1973 Average

Direct Factor Use (1)				Direct Plus Indirect Factor Use (2)		
	A	B			A	B
1. Fuels	2.61	3.11		1. Chemistry	3.94	4.45
2. Machinery and Equipment	2.48	2.98		2. Machinery and Equipment	2.86	3.37
3. Metals	2.33	2.85		3. Fuels	2.42	2.94
4. Conmat	2.12	2.50		4. Industry	2.16	2.65
5. Industry	2.07	2.57		5. Metals	1.95	2.46
6. Chemistry	1.87	2.37		6. Conmat	1.84	2.30
7. Food	1.96	2.31		7. Food	1.37	1.80
8. Light	1.71	2.20		8. Light	1.23	1.73

A = Abramowitz Residual: labor in man years

B = Abramowitz Residual: labor in man years adjusted for changes in man hours

TABLE 3b

Effect of Full Factor Input Measure
On Abramowitz Residuals (w = .68)
(Column 2/Column 1)

SECTOR	A	B
1. Chemistry	2.11	1.88
2. Machinery and Equipment	1.15	1.13
3. Industry	1.04	1.03
4. Fuels	0.98	0.95
5. Conmat	0.87	0.92
6. Metals	0.84	0.86
7. Food	0.72	0.78
8. Light	0.70	0.79

TABLE 4

Abramowitz Residuals
1950-1973 Average

SECTOR	Direct Factor Use (labor in man years) w = .77	SECTOR	Direct-Plus-Indirect Use* (fully adjusted labor) w = .68
1. Fuels	3.25	1. Chemistry	4.04
2. Metals	3.03	2. Machinery and Equipment	2.96
3. Machinery and Equipment	2.87	3. Fuels	2.52
4. Conmat	2.83	4. Industry	2.26
5. Industry	2.69	5. Metals	2.05
6. Chemistry	2.61	6. Conmat	1.93
7. Food	2.57	7. Food	1.46
8. Light	2.29	8. Light	1.33

*The Denison productivity compensation effect is computed as 20% of the difference between entries in columns A and B in Table 3a. See pages 8-9, Chapter II for a more detailed explanation.

TABLE 5

Abramowitz Residuals
Diverse Periods (12% Adjusted Factor Cost and the Conventional Variants)

PERIOD	CHEMICAL		MACHINERY AND EQUIPMENT		FUELS		INDUSTRY		METALS		CONMAT		FOOD		LIGHT	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1950-58	3.99	3.57	4.04	4.38	3.45	3.37	3.59	3.92	3.48	4.65	4.14	4.32	2.99	4.56	3.49	4.52
1959-63	3.81	-0.16	2.23	1.65	2.13	3.51	0.96	1.36	1.46	1.54	-0.20	1.00	-0.12	0.43	-1.92	-0.45
1964-67	4.19	2.17	1.08	0.92	1.12	1.94	1.10	1.61	1.31	2.42	0.50	2.22	1.10	1.52	1.22	1.68
1968-73	4.11	3.75	3.15	2.92	2.37	2.24	2.05	2.67	0.84	2.24	1.31	2.52	0.68	2.05	0.84	1.65

A = Abramowitz residual computed using direct-plus-indirect factor input and adjusted labor in man hours, corrected by the Denison Productivity Factor: $w = .68$. (Computed as 20% of the difference between analogous entries in Tables 7 and 9.)

B = Abramowitz residual computed using direct factor input and labor in average man years: $w = .77$.

TABLE 6

Abramovitz Residual (w = .77)
Diverse Periods: Direct Plus Indirect
Factor Use (Labor in Man Years)

SECTOR

PERIOD	CHEMISTRY	MACHINERY AND EQUIPMENT	FUELS	INDUSTRY	METALS	CONMAT	FOOD	LIGHT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	4.47	4.42	3.90	4.06	3.97	4.69	3.53	3.95
1959-63	4.40	2.62	[illegible]	1.40	2.05	0.36	0.32	-1.50
1964-67	4.77	1.52	1.61	1.59	1.82	1.00	1.54	1.76
1968-73	4.77	3.76	3.08	2.69	1.49	1.97	1.35	1.51

TABLE 7

Abramovitz Residual (w = .68)
Diverse Periods: Direct Plus Indirect
Factor Use (Labor in Man Years)

SECTOR

PERIOD	CHEMISTRY	MACHINERY AND EQUIPMENT	FUELS	INDUSTRY	METALS	CONMAT	FOOD	LIGHT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	3.84	3.92	3.28	3.48	3.31	4.03	2.91	3.41
1959-63	3.68	2.04	1.97	0.74	1.33	-0.42	-0.39	-2.20
1964-67	4.22	1.07	1.12	1.10	1.31	0.49	1.09	1.22
1968-73	4.12	3.16	2.39	2.06	0.84	1.34	0.72	0.84

TABLE 8

Abramowitz Residual (w = .77)
Diverse Periods: Direct Plus Indirect Factor Use
(Labor in Man Years Adjusted for Changes in Man Hours)

	SECTOR							
PERIOD	CHEMISTRY	MACHINERY AND EQUIPMENT	INDUSTRY	FUELS	CONMAT	FOOD	LIGHT	METALS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	5.30	5.11	4.70	4.88	5.31	4.01	4.42	4.92
1959-63	5.11	3.65	2.62	3.54	1.60	1.85	0.04	2.75
1964-67	4.62	1.52	1.59	1.57	1.04	1.56	1.74	1.81
1968-73	4.71	3.70	2.62	2.99	1.76	1.11	1.53	1.50

TABLE 9

Abramovitz Residual (w = .68)
Diverse Periods: Direct Plus Indirect Factor Use
(Labor in Man Years Adjusted for Changes in Man Hours)

SECTOR

PERIOD	CHEMISTRY	MACHINERY AND EQUIPMENT	INDUSTRY	FUELS	CONMAT	FOOD	LIGHT	METALS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	4.57	4.52	4.04	4.15	4.59	3.33	3.82	4.16
1959-63	4.31	2.97	1.83	2.79	0.69	0.98	-0.82	1.97
1964-67	4.08	1.08	1.11	1.10	0.53	1.12	1.21	1.31
1968-73	4.08	3.11	2.00	2.31	1.17	0.52	0.86	0.86

TABLE 10

Abramovitz Residuals (v = .77)
Diverse Periods: Direct Factor Use
(Labor in Man Years)

SECTOR

PERIOD	FUELS	METALS	MACHINERY AND EQUIPMENT	CONMAT	INDUSTRY	CHEMISTRY	FOOD	LIGHT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	3.37	4.65	4.38	4.32	3.92	3.57	4.56	4.52
1959-63	3.51	1.54	1.65	1.00	1.36	-0.16	0.43	-0.45
1964-67	1.94	2.42	0.92	2.22	1.61	2.17	1.52	1.68
1968-73	3.71	2.24	2.92	2.52	2.67	3.75	2.05	1.65

TABLE 11

Abramovitz Residuals (w = .68)
Diverse Periods: Direct Factor Use
(Labor in Man Years)

SECTOR

PERIOD	FUELS	METALS	MACHINERY AND EQUIPMENT	CONMAT	INDUSTRY	CHEMISTRY	FOOD	LIGHT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	2.77	3.96	4.11	3.57	3.28	2.91	3.96	4.12
1959-63	2.87	0.64	1.29	0.04	0.69	-1.15	-0.34	-1.13
1964-67	1.44	1.87	0.53	1.72	1.13	1.44	1.14	1.07
1968-73	2.92	1.62	2.34	1.96	2.04	3.12	1.45	0.90

TABLE 12

Abramowitz Residual (w = .77)
Diverse Periods: Direct Factor Use
(Labor in Man Years Adjusted for Changes in Man Hours)

SECTOR

PERIOD	FUELS	METALS	MACHINERY AND EQUIPMENT	INDUSTRY	CHEMISTRY	FOOD	LIGHT	CONMAT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	4.87	6.10	5.24	4.75	5.03	4.87	4.88	4.96
1959-63	3.85	1.60	2.76	2.47	-0.25	2.35	1.41	2.48
1964-67	1.80	2.43	0.92	1.74	2.13	1.55	1.67	2.22
1968-73	3.56	2.34	2.99	2.69	3.94	1.56	1.78	2.02

TABLE 13

Abramovitz Residual (w = .68)
Diverse Periods: Direct Factor Use
(Labor in Man Years Adjusted for Changes in Man Hours)

	SECTOR							
PERIOD	FUELS	METALS	MACHINERY AND EQUIPMENT	INDUSTRY	CHEMISTRY	FOOD	LIGHT	CONMAT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950-58	4.10	5.24	4.87	4.01	4.20	4.23	4.44	4.14
1959-63	3.17	0.69	2.27	1.67	-1.23	1.36	0.52	1.34
1964-67	1.32	1.88	0.53	1.24	1.40	1.15	1.06	1.72
1968-73	2.79	1.70	2.39	2.05	3.29	1.01	1.02	1.52

A2.1

For those interested in how computed Abramowitz Residuals are effected by the periodization scheme adopted in Chapter II, summary Table A2-1 is provided here as a standard of comparison. Table A2-1 is identical to Table 5 in every way except that equal quinquennia substitute for the historical scheme suggested by Donald Green. Quinquennial counterparts of Tables 6-13 have also been calculated and are available from the author on request.

TABLE A2-1

Abramowitz Residuals
5 Year Averages (12% Adjusted Factor
Cost and the Convention Variants)

PERIOD	CHEMICAL		MACHINERY AND EQUIPMENT		FUELS		INDUSTRY		METALS		CONMAT		FOOD		LIGHT	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1950-54	4.71	5.17	5.90	6.38	2.76	2.91	4.32	4.53	4.51	5.80	3.13	3.86	3.88	5.75	4.90	5.70
1955-59	3.19	2.14	2.31	2.37	3.90	4.07	2.56	2.97	2.03	2.79	4.57	4.15	1.48	2.59	1.65	2.82
1960-64	4.50	-0.40	0.82	0.31	1.75	3.00	0.32	0.98	1.17	1.71	-0.62	1.22	0.78	1.49	-3.59	-1.81
1965-69	3.99	2.88	2.26	2.11	1.68	2.77	1.79	2.25	1.16	2.24	0.83	2.20	0.37	1.25	3.26	3.47
1970-73	4.00	3.99	3.69	3.26	2.46	3.55	2.17	2.72	1.05	2.50	1.58	2.68	0.37	1.55	-0.08	1.03

A = Abramowitz residual computed using direct-plus-indirect factor input, and adjusted labor in mans hours, corrected by the Denison Productivity Factor: w = .68 .

B = Abramowitz residual computed using direct factor input, and labor in average man years: w = .77 .

Chapter II

Notes

1. The residual approach has been widely used in one form or another in research on the Soviet economy. For example see Abram Bergson, "Productivity Under Two Systems: The USSR and the West" in J. Tinbergen, A. Bergson, F. Machlup and O. Morgenstern, Optimum Social Welfare and Productivity: A Comparative View, (Barnes and Noble, New York, 1972) and Bergson, Soviet Post-War Economic Development, The Wicksell Lectures 1974, (Almqvist and Wiksell, Internation, Stockholm, 1974). Outside of the Soviet specialty, the residual technique has been most elaborately developed by Edward Denison. See Edward F. Denison, The Sources of Economic Growth in the United States and the Alternatives before Us, Supplementary Paper No. 13 (Committee for Economic Development, New York, 1962) and Why Growth Rates Differ, (Brookings, Washington, 1967). Also Robert Solow, "Technical Change and Aggregate the Production Function," Review of Economics and Statistics, Vol. 39, August 1957, 312-20.

2. Moses Abramowitz, "Resource and Output Trends in the United States Since 1870," Papers and Proceedings of the American Economic Association, Vol. 46, May 1956, 5-23; Abramowitz, "Economic Growth in the United States," American Economic Review, LII, 1962, 762-82.

3. For interpretation and development of these ideas see John Kendrick, Productivity Trends in the United States, National Bureau of Economic Research (Princeton U.P., 1961) and Evsey Domar, "On Total Productivity and All of That," Journal of Political Economy, Vol. 70, December 1962, 597-608.

4. Robert Solow, "Technological Change and the Aggregate Production Function," Review of Economics and Statistics, Vol. 39, August 1957, 312-20; Solow, "A Skeptical Note on the Constancy of Relative Shares," American Economic Review, Vol. 48, 1958, 618-31; Hebert Levine, "A Small Problem in the Analysis of Growth," Review of Economics and Statistics, Vol. 44, August 1962, 330-2.

5. If factors actually earned the value of their marginal products the distinction here is trivial since the income share would be the product $\partial Y/\partial K \cdot Y/K$ or $\partial Y/\partial L \cdot Y/L$. The Abramowitz specification is slightly weaker than Solow's.

6. In the vast majority of cases the differences are less than 1%.

7. Denison, Why Growth Rates Differ, (Brookings, Washington, 1967), 60-1. At the 40 hour workweek a slight reduction in hours results in a 40% productivity offset. Data for other West European countries are also provided.

8. Denison, ibid, 33-44.

9. Judith Thornton, "Value Added and Factor Productivity," American Economic Review, Vol. 60, December 1970, 863-871.

10. Abram Bergson, Soviet Post-War Economic Development, Wicksell Lectures 1974 (Almqvist and Wiksell, International, Stockholm, 1974). The Japanese labor share was computed from Tables 2 and 4, pages 69-70 as

$$(1) \qquad W = 1 - \frac{\left[\frac{(dY/dL)/dt}{Y/L} - \frac{dR/dt}{R}\right]}{\frac{(dK/dL)/dt}{K/L}}$$

where

$\frac{(dY/dL)/dt}{Y/L}$ = Real national income per employed worker

$\frac{dR/dt}{R}$ = Real national income per employed worker, adjusted for capital stock growth

$(dK/dt)/dt$ = Enterprise fixed capital stock per employed worker.

Notice that the labor share is derived from the Solow equation for the growth residual.

11. Bergson, ibid. Rosefielde, The Transformation of the 1966 Soviet Input-Output Table from Producers' to Adjusted Factor Cost Value, (TEMPO, Washington, 1975), GE75 TMP-47.

12. The CES production function estimates discussed in Chapter III however do suggest that the assumption of transectoral marginal productivity equivalence is ill founded.

13. The data used throughout this study is Stanley Cohn's capital stock series (1970), S. Rapawy's employment series (1975) and the Greenslade-Robertson output series all supplied by Donald Green from the SRI data bank. The series employment in man years, adjusted for changes in man hours was derived for two separate Rapawy series, the first providing man years, the second annual employment per worker.

14. The omitted sectors can easily be incorporated in any extension of this basic research.

CHAPTER III

TECHNICAL PROGRESS AND THE INELASTICITY OF SOVIET FACTOR SUBSTITUTION

A. The Growth Residual

On the basis of the conventional Solow-Abramowitz methodology employed in the preceding chapter, it might be inferred that Soviet postwar sectoral economic growth was largely inputable to an unexamined productivity residual, loosely construed as technical progress.[1] Denison, among others however, has stressed that strictly speaking technical progress is only a small component of residual growth.[2] Lumped together under the rubric of technical progress are an improved composition of the capital stock, increased educational attainment, demographic variations, changes in the character of abstract technology, the influence of returns to scale and the elasticity of factor substitution. Each of these factors in part contribute to the residual. Their measurement however is not invariant to the functional form employed initially to estimate the residual itself. For example, the Solow-Abramowitz residual assumes a unitary elasticity of substitution, and constant income factor shares across sectors. If either of these assumptions is false, then computed residuals may diverge from their true values.

In this chapter we attempt to isolate technological progress from other obscuring aspects of the Solow-Abramowitz residual. In particular, attention is focused on the role played by the elasticity of substitution in affecting the measurement of technical progress. The specification chosen for this purpose is a logarithmic variant of the CES form adopted by Weitzman in his study of aggregate postwar Soviet industrial production.[3]

$$\ln Y(t) = \ln\gamma + \lambda t - \frac{1}{\rho}\ln[\delta K(t)^{-\rho} + (1-\delta)L(t)^{-\rho}] \quad (1)$$

The output Y of each sector is stipulated to be a function of:

γ = an efficiency scale parameter

λ = an exponential rate of sectoral growth assuming Hicks neutral technical change

t = time

ρ = a factor substitution parameter related to the elasticity of factor substitution $\sigma = 1/1 + \rho$, and $\rho = (1-\sigma)/\sigma$

δ = the capital intensity parameter

K = capital

$1-\delta$ = the labor intensity parameter

L = labor .

The bracketed term (t) indicates that the data pertain to time series rather than cross sectional observations. Although equation (1) may appear unusually complicated, it is closely akin to the familiar Cobb-Douglas form, which constitutes the special CES case where the elasticity of factor substitution is unity (σ=1),[4]

$$Y = \gamma e^{\lambda t}K^{\delta}L^{1-\delta} = \gamma e^{\lambda t}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-\frac{1}{\rho}} \quad (2)$$

$$\text{if } \sigma = 1, \text{ or } \rho = \frac{1}{\sigma} - 1 = 0 \ .$$

Thus the CES specification has the double virtue of subsuming the conventional Cobb-Douglas type while at the same time encompassing all of the aspects of abstract technology discussed in Chapter I.

The particular expression presented in equation (1) is not the only possible CES form. If technical progress were anticipated to be Harrod neutral the alternative specification

$$Y = \gamma[\delta K^{-\rho} + (1-\delta)(e^{\alpha t}L)^{-\rho}]^{-\frac{1}{\rho}} \quad (3)$$

could be used attributing all the gains from technical progress to labor[5]

$$(4) \qquad F(K,L,t) = G[K,A(t)L] \quad .$$

Likewise, if technical progress were biased and factor augmenting the form

$$(5) \qquad Y = \gamma[(\alpha(t)K)^{-\rho} + (\beta(t)L)^{-\rho}]^{-\frac{1}{\rho}}$$

might be utilized.[6] If returns to scale seem important, a special parameter could be introduced to account for its impact,[7]

$$(6) \qquad Y = \gamma e^{\lambda t}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-\frac{\nu}{\rho}}$$

$$\nu = \nu(0 \ldots, \infty) \quad .$$

Notice that all these variants, and others as well, presume that the composition of the capital, labor, and output aggregates remain constant. If this presumption is false, adjustments will be required on the data itself. In attempting to isolate the magnitude of domestic technical progress in the strict sense therefore, it is not enough merely to choose the correct functional form. The data must be consistently defined and classified in a manner that accurately reflects the production process.

Given the time constraints placed on this present study, a comprehensive investigation of all data sets for all plausible specifications, for every sector was deemed infeasible. As will soon be clear however, the Hicks neutral specification (equation (1)) in conjunction with the special Cobb-Douglas case (equation (2)) provide a good starting point for the systematic investigation of postwar sectoral Soviet economic growth.[8] Like the preceding chapter, statistics will be presented based on alternative classifications of originating sectors for capital and labor. Although an adjusted labor input series was also computed, these results have been suppressed because of their dubious theoretical merit and their generally inferior statistical characteristics.[9]

B. Estimation of the CES Production Function

Equation (1) was estimated with a two stage linear, non-linear procedure. This strategy was prompted by the starting point problem.[10] As Kumar and Asher have shown, the parametric estimates obtained from a non-linear regression often depend on the initial values specified in starting the search process. Therefore it is desirable to find some device that efficiently selects starting values likely to globally minimize the logarithmic sum of squared resuduals.[11] A priori considerations are of some help. Meaningless values which violate the assumptions of production theory such as $\delta > 1$, $\delta < -1$ (i.e. $\sigma < 0$) can be easily eliminated. However, a great deal of latitude remains and a complementary technique suggested by Kmenta has been adopted.[12] In the first stage ordinary least squares regression is employed to estimate the linear approximation of equation (1),

$$(7) \qquad \ln[Y(t)/L(t)] = \ln\gamma + \lambda t + \delta\ln[K(t)/L(t)]$$

$$- \frac{1}{2}\rho\delta(1-\delta)\{\ln[K(t)/L(t)]\}^2$$

The OLS estimates $\hat{\gamma}$, $\hat{\lambda}$, $\hat{\delta}$ and $\hat{\rho}$ are then used as the initial values for the non-linear estimation of equation (1).[13] This technique worked exceedingly well in a test case that replicated Weitzman's estimates for the aggregate postwar Soviet industrial production function.[14] In the main, they proved useful once again at the sectoral level, although they tended to under-estimate ρ substantially when the elasticities of factor substitution were extremely low. As a check alternative starting values were selected in various instances, none of which counter-indicated the Kmenta approximation.

C. The Sectoral Character of Soviet Postwar Production: The Hicks Neutral CES Case

Tables 1 and 2 present non-linear parametric estimates of the abstract character of Soviet sectoral technology for seven branches of the national economy. An aggregate industrial measure is also provided in two variants, the first using conventional value added weights, the second direct-plus-indirect adjusted factor cost weights derived from an input-output algorithm.[15] The second is the conceptually preferable measure. Table 1 is based on the vertically integrated classification of sectoral inputs where all capital and labor regardless of their nominal sector of origin are attributed to the sector of final product delivery. Table 2 reflects traditional sectoring where factors are classified by originating sector. As was argued in Chapter 2 the former classification better accords with the common sense conception of all delivered final goods as a complete product representing the value added sum of inputs at all stages of production, as opposed to the alternative specification where the product is treated in terms of the intrasectoral "assemblage" value added. Since the preferability of these measures hinges on the analytical issues in question, both types of data are employed here for purposes of comparison.[16]

It is readily apparent even on casual inspection that the sectoring convention chosen has little systematic importance. The R^2's in Table 1 in most cases exceed those of Table 2 by a small margin, however a striking inelasticity of factor substitution characterizes both sets of results. The major superiority achieved by the vertically integrated sectoring scheme occurs in the machinery and equipment sector. Using the traditional sector classification no set of best parametric estimates can be found because the minimization routine generates factor intensity parameters, $\delta > 1$, along with negative values for the elasticity of factor substitution.[17] Since factor substitution elasticities are defined over the range zero to infinity, negative values of σ are meaningless. The same problem emerges in the light

industrial sector. Overall, with the exceptions noted, the CES specification yields statistically significant estimates of the various parameters at the .95 percent confidence level, suggesting that previous studies emphasizing the role played by the elasticity of substitution in the retardation of Soviet economic growth were not only accurate in the aggregate, but in sector detail as well.[18]

Regarding relative rates of technical progress among sectors, Table 3 indicates that the particular configurations of abstract technology in each sector alter growth residual rank orderings by branch. While the range and magnitude of the growth residuals remain much the same, the relative performance of the sectors varies considerably. Clearly, relative sectoral efficiency depends on the special characteristics of abstract technology prevailing in each sector.[19]

This last point is dramatically demonstrated by comparing the capital and labor income shares implied by the CES estimates with those imposed on the Solow-Abramowitz residual analysis. Income shares in the CES world are computed from appropriate marginal factor productivities and factor output ratios.

$$(8) \qquad \theta_X(t) = \frac{X}{Y}\frac{\partial Y}{\partial X}$$

or more specifically,[20]

$$(9) \qquad \theta_K(t) = \delta\gamma^{-\rho}e^{-\lambda\rho t}(Y(t)/K(t))^{\frac{1}{\sigma}}\ (Y(t)/K(t))^{-1}$$

$$= \delta\gamma^{-\rho}e^{-\lambda\rho t}(Y(t)/K(t))^{\rho}$$

and

$$(10) \qquad \theta_L(t) = (1-\delta)\gamma^{-\rho}e^{-\lambda\rho t}\ (Y(t)/K(t))^{\rho}\ .$$

Table 1

Estimates of Abstract CES Technology
(Direct-Plus-Indirect Inputs)

Sector	γ	λ	δ	ρ	σ	R^2	Iterations
Fuel	.9845	.0184	.5706	1.0120	.4970	.9978	6
Metal	1.0230	.0276	.5349	2.9000	.2564	.9988	4
Construction Material	1.0140	.0297	.4537	2.8230	.2616	.9888	10
Chemical	1.0030	.0577	$.2\times10^{-9}$	3.4180	.2263	.9983	7
Machinery and Equipment	1.0170	.0246	.6226	2.3960	.2945	.9932	10
Light	-	-	-	-	-	-	2
Food	1.0220	.0243	.6565	5.6490	.1504	.9976	5
Industry	1.0020	.0308	.6059	4.9380	.1684	.9977	10
Industry 12% AFC	1.0070	.0292	.6405	6.4880	.1335	.9973	10

See footnote 18 for the standard errors of these parameters and their corresponding t values.

Table 2

Estimates of Abstract CES Technology
(Direct Inputs)

Sector	γ	λ	δ	ρ	σ	R^2	Iterations
Fuel	.9763	.0160	.5446	.4163	.7061	.9981	2
Metal	1.0020	.0355	.6314	4.3260	.1878	.9993	10
Construction Material	.9994	.0278	.4464	1.5340	.3946	.9966	4
Chemical	.9955	.0342	.7511	11.8400	.0779	.9954	10
Machinery and Equipment	-	-	-	-	-	-	5
Light	-	-	-	-	-	-	5
Food	1.0070	.0266	.8775	7.8430	.1131	.9975	4
Industry	1.0220	.0270	.4482	2.2610	.3067	.9971	10
Industry 12% AFC	1.0280	.0283	.4418	3.6580	.2149	.9968	10

See footnote 18 for the standard errors of these parameters and their corresponding t values.

Table 3

Technical Progress (λ)

Sector	CES (Direct-Plus-Indirect Inputs)	Abramowitz (w=.77) (Direct-Plus-Indirect Inputs)
Chemicals	5.73	4.58
Industry	3.08	2.75
Construction Materials	2.97	2.49
Metals	2.76	2.59
Machinery and Equipment	2.46	3.40
Food	2.43	1.99
Fuels	1.84	3.05

They vary annually with the output-input ratio $(Y(t)/K(t))$, and are analogous to the time derivatives used in the Solow-Abramovitz calculation.

Sectoral factor income share values are presented in Tables 4 and 5. The underlying parametric estimates are drawn respectively from Tables 1 and 2. Except for the effect of the error term in Equation (1), θ_k and θ_l should sum to one.

Regardless of the sectoring convention, a pronounced tendency for the capital income share to approach zero is manifested in eleven of the fifteen branches of the Soviet economy for which calculation could be made. Only the fuel sector diverges from this pattern on both CES measures. The behavior of these CES capital income shares is more than a curiosa. While Table 3 had suggested an ostensible concordance between CES and Solow-Abramowitz technical progress, the findings in Tables 4 and 5 demonstrate that such similarities belie a fundamental difference in projectable growth possibilities. If the CES description is accurate sustainable Soviet growth is limited essentially to the gains afforded by Hick's neutral technical progress supplemented by the secular growth of the industrial labor force.[21] This implies a rate of growth substantially below the Solow-Abramowitz rate where the output elasticity of capital is assumed to be constant over time. The impact of the elasticity of substitution parameter therefore significantly colors our interpretation of the sector pattern of Soviet growth and as we shall see shortly has important implications for assessing the magnitude of the possible contribution made by East-West trade on the recent Soviet growth experience.

D. Cobb-Douglas Sectoral Estimates

Because the inelasticity of factor substitution plays such a decisive role in governing the behavior of factor income shares according to our CES

Table 4

Capital and Labor Income Shares (percent)
(Direct-Plus-Indirect Inputs)

	Industry 12% AFC		Industry		Fuel		Metal		Construction Material		Chemical		Machinery and Equipment		Food	
	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l
1950	60	39	60	34	58	44	50	44	44	53	0	98	60	36	58	30
1955	19	88	24	78	47	51	29	74	22	70	0	104	51	62	21	75
1960	4	106	8	100	42	60	14	85	14	108	0	95	34	71	5	97
1965	0	87	1	89	33	66	5	95	4	97	0	102	17	72	1	114
1970	0	99	0	96	27	72	2	97	2	91	0	99	11	84	0	103
1973	0	119	0	115	23	79	1	98	1	96	0	101	8	107	0	100

Table 5

Capital and Labor Income Shares (percent)
(Direct Inputs)

	Industry 12% AFC		Industry		Fuel		Metal		Construction Material		Chemical		Food	
	θ_k	θ_1	θ_k	θ_1	θ_k	θ_1	θ_k	θ_1	θ_k	θ_1	θ_k	θ_1	θ_k	θ_1
1950	39	50	43	53	55	46	63	37	45	55	79	26	83	12
1955	17	88	26	76	50	49	29	77	36	62	24	104	44	56
1960	7	99	16	84	49	52	7	91	27	73	0	124	5	99
1965	2	89	8	87	45	55	1	98	16	77	0	66	0	119
1970	1	98	4	94	41	59	0	96	13	80	0	98	0	106
1973	0	109	3	104	39	61	0	100	11	82	0	197	0	108

estimates, it is useful to compare these findings with parametric estimates generated from the more restrictive Cobb-Douglas specification. As was noted previously, the Cobb-Douglas production function represents the special CES case where the elasticity of substitution is one. By forcing $\rho = 0$, equation (1) can be transformed into equation (2), with three rather than four unknown parameters. Tables 6 and 7 report the results of these nonlinear estimates, the former based on the vertically integrated classification scheme, the latter on the direct input convention. In every case except the machinery and equipment sector (Cf Table 1 and Table 6), the CES coefficient of determination exceeds its Cobb-Douglas counterpart. Using an F test on the adjusted difference in the sum of squared residuals suggested by Weitzman,[22] the null hypothesis that the Cobb-Douglas specification is the true form is rejected at the 95 percent confidence level in 13 out of the 15 cases where comparisons are possible. Given all the vagaries inherent in the basic data, tests of this sort cannot be completely decisive, but an examination of the test point values generated during the iterative minimization procedure on the CES specification makes it very clear that a unitary or near unitary elasticity of substitution is attainable only by arbitrarily restricting ρ in the vicinity of zero.

Moreover, Cobb-Douglas factor income shares and the growth patterns they imply seem implausible. Cobb-Douglas factor income share values are presented in the δ column of Tables 6 and 7. The factor intensity parameter is equivalent to the factor income share when $\rho = 0$, since

(11) $\theta_K(t) = \delta\gamma^{-\rho}e^{-\lambda\rho t}\,(Y(t)/K(t))^{\rho} = \delta$

(12) $\theta_L(t) = (1-\delta)\gamma^{-\rho}e^{-\lambda\rho t}(Y(t)/K(t))^{\rho} = 1 - \delta$.

As is easily seen, Cobb-Douglas and CES measures of both δ and λ are similar in the chemical sector, but not elsewhere. In every case (fuels, metals, construction materials, machinery and equipment, industry and industry 12% AFC in Table 6 where the income share attributable to capital is significant, the rate of Hicks neutral technical progress becomes negligible. Where residual growth is important, the output elasticity of capital is approximately zero throughout the postwar period. The same tendencies in a less pronounced form are exhibited in Table 7. The behavior inferable from these statistics appear aberrant. On one hand, rapid technical progress is concentrated in the consumers' goods sectors, which with their relatively low capital intensity are characterized by zero marginal capital productivity. On the other hand, capital abundant heavy industry exhibits relatively high marginal productivities of capital, but generates no neutral technical change.

These patterns are precisely the reverse of those one might anticipate on the basis of theory,[23] suggesting that the Cobb-Douglas specification is not an accurate representation of abstract technology at the sectoral level of the Soviet economy. If this argument is granted, it appears that the CES specification, utilizing the vertically integrated classification scheme, is the best tentative functional form describing the character of postwar Soviet sectoral production. Given the limited nature of this study, it cannot be claimed that other still more powerful specifications do not exist which should be preferred to the Hicks neutral variant of the CES production function. However, one additional and important aspect of our findings contribute to their general cogency.

In Chapter I it was argued that changes in the aggregate composition of goods and services could have a significant effect on the parameters of aggregate abstract technology. This potentially disturbing factor apparently

Table 6

Estimates of Abstract Cobb-Douglas Technology
(Direct-Plus-Indirect Inputs)

Sector	γ	λ	δ	R^2	Iterations
Fuels	1.0680	.0042	.5718	.9967	5
Metal	1.1490	$.1\times10^{-5}$	.5196	.9955	10
Construction Materials	1.1530	$.7\times10^{-5}$	.4861	.9837	7
Chemicals	1.0950	.0526	$.1\times10^{-5}$	.9938	10
Machinery and Equipment	1.1290	$.2\times10^{-4}$	.6908	.9933	10
Light	1.1670	.0246	$.8\times10^{-5}$	.9703	10
Food	1.1200	.0296	$.3\ 10^{-6}$	.9726	10
Industry	1.1190	.0017	.5387	.9954	5
Industry 12% AFC	1.1160	.0090	.3759	.9951	5

See footnote 23 for the standard errors of these estimates and their corresponding t values.

Table 7

Estimates of Abstract Cobb-Douglas Technology
(Direct Inputs)

Sector	γ	λ	δ	R^2	Iterations
Fuels	1.0200	.0111	.5193	.9977	4
Metals	1.1570	.0184	.2867	.9952	4
Construction Materials	1.0940	.0197	.2727	.9939	4
Chemicals	1.0090	.0398	$.1\times10^{-4}$	.9928	10
Machinery and Equipment	1.1800	.0157	.3012	.9906	4
Light	1.1570	.0288	$.2\times10^{-5}$	.9796	10
Food	1.1930	.0116	.3200	.9893	4
Industry	1.0930	$.6\times10^{-6}$	.5619	.9964	9
Industry 12% AFC	1.0930	$.1\times10^{-4}$	.5184	.9959	10

See footnote 23 for the standard errors of these estimates and their corresponding t values.

is not consequential in postwar Soviet experience even though the various branches of the national economy expanded at diverse rates because all sectors whether primary, secondary or tertiary are characterized by low elasticity of substitution parameters and sharply falling capital income shares. This surprising intersectoral consistency not only means that the impact of structural change on aggregate specification has been small, it also suggests the intriguing hypothesis that the inelasticity of sectoral factor substitution has a common cause across the branches of the national economy. Put succinctly, in the Soviet context where quality and assortment are especially troublesome a strong propensity might exist against designing equipment that embodies flexible technological capabilities. If design flexibility is achieved at increasing material, engineering and bureaucratic cost, equipment may well be constructed with limited regard for the chargeability of the economic environment. The absence of market prices would tend to reinforce nominal cost savings of this sort, because no unambiguous indicators are available to alert designers to variations in relative marginal factor productivities. If Soviet technology is indeed inflexible and designers insensitive to changing relative factor scarcities, the inelasticity of factor substitution across sectors is not only statistically valid, it accords with common sense, reflecting deep problems of quality and assortment in a bureaucratically controlled economy. Moreover, in the context of our study, the institutional factors fostering the design of inflexible embodied technologies provides a plausible rationale for selecting a CES specification with Hick's neutral technological progress over alternatives with less a priori credibility.

E. Summary

Despite the large number of potential difficulties obscuring a genuinely decisive identification of the true specification of postwar Soviet sectoral production, our calculations have shown that the Hick's neutral version of the CES production function yields parametric estimates which are superior to both Cobb-Douglas or Solow-Abramowitz alternatives. This is true whether sectors are classified according to the vertically integrated format or on the basis of direct inputs. It is true whether conventional or adjusted factor cost values are employed and its validity is probably independent of the structural changes in the branch composition of aggregate output that have occurred during the past twenty four years.

Generally speaking the CES specification portrays postwar Soviet sectoral growth in terms of moderate rates of Hick's neutral technological progress, approximately 3%, conjoined with rapidly declining capital income shares. This characterization implies that future Soviet growth may be profoundly linked to the possibilities for sustaining or enhancing past rates of technical change especially so if as we suspect observed inelasticities of factor substitution stem from the high institutional cost of designing flexible technologies in a bureaucratically organized economic system.

Chapter III

Notes

1. The term Solow-Abramowitz is used here to encompass both types of productivity residual calculations. See Chapter II.

2. Edward Denison, Why Growth Rates Differ, (Brookings, Washington, D.C., 1967).

3. Weitzman's equation is $Y(t) = \gamma e^{\lambda t}[\delta K(t)^{-\rho} + 1-\delta(L(t))]^{-1/\rho}$. See Martin Weitzman, "Soviet Postwar Economic Growth and Capital-Labor Substitution," AER, IX, #4, September 1970, p. 680. Also see K.J. Arrow, H.B. Chenery, B.S. Minhas and R.M. Solow, "Capital Labor Substitution and Economic Efficiency," Review of Economics and Statistics, August 1961, Vol. 43, 225-50.

4. $\lim_{\rho\to 0} Y = \lim_{\rho\to 0} \gamma[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-1/\rho}$

$$= \frac{\gamma L}{[\delta(L/K)^{\rho} + (1-\delta)]^{1/\rho}} = \frac{\gamma L}{1^{\infty}}$$

which is an indeterminate form. Applying L'Hospital's Rule to the logarithm of the denominator,

$$\lim_{\rho\to 0} \ln Z = \lim_{\rho\to 0} \frac{\delta e^{\rho \ln(L/K)} \ln L/K}{[\delta(L/K)^{\rho} + (1-\delta)]} = \delta \ln(L/K)$$

$$\lim_{\rho\to 0} Z = (L/K)^{\delta}$$

so that

$$\lim_{\rho\to 0} Y = \frac{\gamma}{(L/K)^{\delta}} = \gamma L L^{-\delta} K^{\delta} = \gamma K^{\delta} L^{1-\delta} \quad .$$

See Charles Ferguson, The Neoclassical Theory of Production and Distribution, (Cambridge University Press, Cambridge, 1969), p. 106.

5. Hirofumi Uzawa, "Neutral Inventions and the Stability of Growth Equilibrium," Review of Economic Studies, XXVIII, pp. 119-20.

6. See Ferguson, ibid, 244. Gomulka has estimated this CES variant. See Stanislaw Gomulka, "Soviet Post-War Industrial Growth, Capital Labour Substitution and Technical Changes: A Reexamination," Paper presented at the BANFF Conference, September 1974.

7. See Murry Brown, On the Theory and Measurement of Technological Change, (Cambridge University Press, Cambridge, 1968).

8. A single test of the CES specification assuming Harrod neutral technical change was conducted on the adjusted factor cost industrial aggregate based on the vertically integrated classification format. Not only was the coefficient of determination comparatively inferior, the exponential labor augmenting parameter α was miniscule, $.3\times10^{-6}$, with a standard deviation of .05 and a t value of $.7\times10^{-5}$ clearly insignificant at an reasonable level of confidence. On the basis of these results a more comprehensive set of sectoral computations was deferred.

In Chapter I we noted that CES parameters may not have normal distributions so that standard F and t tests are to be treated tongue in cheek. Kumar and Gapinski however have recently studied the sampling distribution of CES parameters and conclude that σ is non-normal, λ is normal if $\sigma < 1$, and δ is often normal, γ is never normal. Caveat emptor! See T. Krishna Kumar and James Gapinski, "Nonlinear Estimation of the CES Production Function: Sampling Distributions and Tests in Small Samples," Southern Economic Journal, Vol. 41, #2, October 1974, 258-66. Also Kumar and Gapinski, "Nonlinear Estimation of the CES Production Parameters: A Monte Carlo Study," Review of Economics and Statistics, November, 1974.

9. As was pointed out in Chapter II, Denison has argued that reductions in man hours employed are offset by compensatory increases in labor productivity. In the Soviet case this offset is considerable. If allowance is made for the productivity effect little change occurs in our estimates of abstract technology. If unadjusted man hour data are employed the following estimates obtain:

Table N1

Estimates of Abstract CES Technology
(Direct Inputs, Labor in Man Years
Adjusted for Annual Man Hours Per Worker)

Sector	γ	λ	δ	ρ	σ	R^2	Iterations
Fuel	.9555	$.5\times10^{-7}$	.8897	1.0410	.4900	.9971	9
Metal	.9933	.0278	.7341	2.2260	.3100	.9984	4
Construction Material	.9962	.0151	.6792	1.1450	.4082	.9963	4
Chemical	.9809	.0362	.7710	5.8010	.1470	.9953	10
Machinery and Equipment	-	-	-	-	-	-	1
Light	1.0190	.0288	.8575	6.7400	.1292	.9888	7
Food	1.026	.0169	.8252	2.8630	.2589	.9965	4
Industry	1.0220	.0001	.7995	.9594	.5104	.9955	9
Industry 12% AFC	1.0280	.0043	.7102	.9052	.5248	.9946	4

Table N2

Standard Errors of the CES Parameter Estimates and t Statistics (Direct Input, Labor in Annual Man Hours) Labor in Man Year, Adjusted for Changes in Annual Man Hours per Worker)

Sector	γ		λ		δ		ρ	
	s	t	s	t	s	t	s	t
Fuel	.0113	84.2	.0873	$.6\times10^{-5}$	.1004	8.9	.4321	2.4
Metal	.0102	97.6	.0027	10.5	.0250	29.3	.2675	8.3
Construction Material	.0141	70.6	.0041	3.7	.0411	16.5	.1989	5.8
Chemical	.0219	44.8	.0025	5.7	.1344	5.7	2.5270	2.3
Machinery and Equipment	-		-		-		-	
Light	.0220	46.3	.0028	10.3	.0951	9.0	2.5030	2.7
Food	.0129	79.4	.0025	6.7	.0334	24.7	.3789	7.6
Industry	.0188	54.4	.0157	$.3\times10^{-2}$	.1446	5.5	.2490	3.9
Industry 12% AFC	.0200	51.3	.0160	.27	.1460	4.8	.3521	2.5

Moreover, factor income shares decline at reasonable rates in industry as a whole.

Table N3

Capital and Labor Income Shares (percent) (Direct Inputs, Labor in Man Years, Adjusted for Changes in Annual Man Hours per Worker)

	Industry 12% AFC		Industry		Fuels		Metals		Construction Materials		Chemicals		Light		Food	
	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l	θ_k	θ_l
1950	69	28	78	20	93	12	75	27	41	59	86	26	76	13	77	16
1955	63	36	72	26	81	15	55	44	37	62	45	50	67	39	70	34
1960	56	47	68	36	80	23	29	73	31	72	6	118	16	101	36	59
1965	45	53	55	43	72	30	11	87	22	77	0	90	0	65	16	93
1970	40	60	50	50	63	36	7	93	19	80	0	104	0	119	9	92
1973	36	65	96	56	57	43	5	99	18	84	0	138	0	107	5	97

These positive aspects appear to lend credence to Stanislaw Gomulka's approach. See Stanislaw Gomulka, "Soviet Postwar Industrial Growth, Capital-Labor Substitution and Technical Changes: A Reexamination," Paper presented to the BANFF International Conference, (September 1974).

Caution however is advised for several reasons. First, the implausibly low estimate of Hicks neutral technical progress viewed against the moderately high rates achieved by each individual sector suggests that the Denison effect should be taken seriously. Second, if the aggregate cases are overlooked in Table N1, then the behavior of factor income shares are not unlike those obtained before labor is adjusted. Finally, the estimates reported here are based on the dispreferred direct input classification, time constraints having precluded computation of estimates from the data classified according to the vertical integration norm.

10. See T. Kumar and E. Asher, "Soviet Postwar Economic Growth and Capital Labor Substitution: Comment," American Economic Review 64, (March 1974), 210-42.

11. Weitzman, ibid.

12. See Dorothy Hodges, "A Note on Estimation of Cobb-Douglas and CES Production Function Models," Econometrica, Vol. 37, (October 1969), pp. 721-5. J. Kmenta, "On Estimation of the CES Production Function," International Economic Review, 8, (June 1967), 229-38.

13. A nominal linear regression package "Logit," based on the Marquardt algorithm was utilized.

14. Weitzman, ibid., 681. Also Rosefielde and Lovell, "The Impact of Adjusted Factor Cost Valuation on the CES Interpretation of Postwar Soviet Economic Growth," UNC Working Paper Series, March 1976.

15. Steven Rosefielde, The Transformation of the 1966 Soviet Input-Output Table from Producers' to Adjusted Factor Cost Values, (TEMPO, Washington, 1975), GE75TMP-47.

16. Footnote 8 provides estimates analogous to Table 2 based on man hour instead of man year data. The t values for these statistics are almost all significant at the 95 percent confidence level.

17. More exactly the ordinary least square approximation (equation (7)) to equation (1) produces these negative elasticities. The nonlinear minimization procedure itself aborts as soon as $\delta > 1$, since the log of the negative product $(1-\delta)L^{-\rho}$ is undefined. Just before δ becomes greater than 1, $\sigma \to 0$.

18. Tables N4 and N5 provide information on the standard errors of each parameter displayed in Tables 1 and 2. T statistics are also shown. All values greater than 2.1 are significant at the 95 percent confidence level, those greater than 1.6 at the 90 percent confidence level.

Notice also that the sector diversity of the production function contradicts Gomulka's conjecture on aggregation. See Gomulka, op. cit., 10.

Table N4

Standard Errors of the CES Parameter Estimates and t Statistics
(Direct-Plus-Indirect Inputs)

Sector	γ s	γ t	λ s	λ t	δ s	δ t	ρ s	ρ t
Fuels	.0117	84.0	.0174	1.1	.2498	2.8	.3261	3.1
Metals	.0099	103.1	.0027	10.3	.0428	12.5	.8051	3.6
Construction Materials	.0301	33.7	.0067	4.4	.1583	2.9	2.9020	1.0
Chemicals	.0135	74.3	.0017	34.5	.0800	$.3\times10^{-8}$	$.5\times10^{7}$	$.6\times10^{-6}$
Machinery and Equipment	.0246	41.3	.0245	1.0	.3192	2.0	1.9240	1.2
Light	-		-		-		-	
Food	.0132	77.4	.0014	17.9	.09051	7.3	1.6510	3.4
Industry	.0147	68.1	.0019	16.1	.1051	5.8	1.977	2.5
Industry 12% AFC	.0158	63.7	.0015	20.0	.1359	4.7	2.8120	2.3

Table N5

Standard Errors of the CES Parameter Estimates and t Statistics
(Direct Inputs)

Sector	γ		λ		δ		ρ	
	s	t	s	t	s	t	s	t
Fuel	.0127	76.9	.0094	1.6	.1848	2.9	.2119	2.0
Metals	.0080	124.8	.0012	30.6	.0422	15.0	.5975	7.2
Construction Materials	.0144	69.4	.0041	6.7	.0567	7.9	.4684	3.3
Chemical	.0193	54.2	.0017	22.2	.0123	.2	6.9760	.7
Machinery and Equipment	-		-		-		-	
Light	-		-		-		-	
Food	.0129	78.3	.0012	22.6	.0540	16.2	1.7140	4.6
Industry	.0163	62.6	.0092	2.9	.0632	7.1	1.6730	1.4
Industry 12% AFC	.0162	63.3	.0029	9.8	.1155	4.1	2.2670	1.9

With 23 degrees of freedom, the t value for both tails at the 95 percent confidence interval is 2.069, for the 90 percent confidence interval 1.645.

19. The standard errors of λ in the machinery and equipment and fuel sectors are large and their t values insignificant at the 95 percent confidence. The rank orderings shown in Table 3 therefore should not be considered entirely firm.

20. See Brown, ibid.

21. An arithmetic example might be helpful here. Suppose that the capital and labor supplies were equal, $K/L = 1$, $K = 100$, $L = 100$. Suppose further that $\rho = .5$, $\delta = .5$, $\lambda = 0$, $\gamma = 1$. Table N5 shows the effect of rapid capital growth relative to labor (or of course vice versa) on output, Y.

Table N6

Factor Inelasticity and Output

$$Y = [\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-1/\rho}$$

Y	K	L
100	100	100
80	150	50
52	175	25
3.5	199	1

These results reflect both the falling marginal productivity of capital and the declining capital share.

22. Weitzman, ibid, p. 683.

23. Usually marginal productivities are inversely, not positively correlated with relative scarcities. Also it should be noted that the t statistics for the Cobb-Douglas specification were generally inferior as can be seen in Table N7.

Table N7

Standard Errors of the Cobb-Douglas Parameter Estimates
and t Statistics
(Direct-Plus-Indirect Inputs)

Sector	γ		λ		δ	
	s	t	s	t	s	t
Fuel	.0143	74.9	.0128	.3	.2016	2.8
Metal	.0193	59.6	.0178	$.8\times10^{-4}$	.2728	1.9
Construction Material	.0309	37.3	.0222	$.3\times10^{-3}$	.3315	1.5
Chemical	.0306	35.8	.0014	37.6	.0089	$.1\times10^{-3}$
Machinery and Equipment	.0250	45.2	.0172	$.1\times10^{-2}$	.3088	2.2
Light	.0424	27.5	.0332	.7	.6177	$.2\times10^{-4}$
Food	.0363	30.9	.0078	3.8	.1300	$.2\times10^{-5}$
Industry	.0166	67.2	.0182	.1	.2963	1.8
Industry 12% AFC	.0163	68.7	.0182	.5	.2963	1.3

Appendix to Chapter III

SUPPLEMENTARY EVIDENCE REGARDING THE CHARACTER OF ABSTRACT SOVIET TECHNOLOGY

Although Chapter III is self-contained various issues are implicitly raised which require further explanation. Rather than break the continuity of the preceding argument these problems are discussed independently.

A3.1 The "Catch Up Effect"

The findings of the preceding section assume that the entire postwar period from Stalin to Brezhnev can be treated as a single epoch. Both Donald Green and Stanislaw Gomulka have suggested that the "catch-up" effect associated with the early reconstruction phase of the postwar Soviet recovery should extend not to 1950 but to 1955. Indeed in Chapter II we observed that the Abramowitz residual during the years 1950-1958 far exceeded the rate of technical progress achieved in any subsequent period. To test the inference that the low elasticity of capital labor substitution is the result of incorrectly pooling observations from discrete epochs, the twenty four year time series used in our previous calculations was truncated to 19 years, 1955-1973. Tables A3.1-1 and A3.1-2 report estimated parameters and their t tests respectively for our preferred direct-plus-indirect factor measure, labor computed in man years. Two aspects of these findings require particular attention. First, the low elasticity of factor substitution is sustained in all instances. Adjustment to the lower average growth rate of the truncated series is diversely expressed. In some cases λ, Hicks neutral technical progress declines, in others σ, the capital labor substitution elasticity falls (increasing the rate at which diminishing returns set in), while in the single case of aggregate industrial production δ, the factor intensity parameter exhibits an extremely low value. Clearly, the "catch-up" phenomenon, important in itself, has no systematic impact on the character of estimated abstract technology and does not appear to invalidate the conclusions previously drawn by Weitzman, Rosefielde-Lovell, and Rosefielde. The extreme inelasticity of factor substitution remains the distinctive characteristic of postwar Soviet abstract technology.

Second, even allowing for the interpretational problems of tongue-in-cheek t tests, the statistical power of the estimated parameters for the Khrushchev-Brezhnev epoch is exceedingly low. Not only is this important for establishing the relative merit of the two postwar series, it may also explain Stanislaw Gomulka's finding based on a truncated series, that the elasticity of factor substitution is not significantly different than unity, implying that the Cobb-Douglas specification accurately depicts postwar Soviet growth. Experimentation with the starting values for the CES estimation of aggregate industry, using adjusted factor cost weights revealed that the Cobb-Douglas result could easily be obtained by judiciously selecting initial parameter test points. The estimates reported above had the highest coefficient of determination, $R^2 = .9951$. However in three ancillary calculations on the same data with R^2s between .9942 and .9947, ρ was not significantly different from 0, suggesting the Gomulka result $\sigma \simeq 1$. On the basis of these findings one is forced to conclude that the surprising reversal demonstrated by Gomulka in the magnitude of the capital labor substitution parameter was largely due to the volatility of nonlinear estimates in small time series to the selection of initial parametric starting values. Had Gomulka experimented with other test points, I suspect he would have discovered that his Cobb-Douglas finding was fortuitous and statistically inferior to alternative estimates.

Table A3.1-1

Alternative CES Estimates
"The Khrushchev-Brezhnev Epoch"
Using Direct-Plus-Indirect Input,
Labor in Man Years, Observations 1955-1973

Sector	γ	λ	δ	ρ	σ	R^2	Iterations
Fuel	1.0340	.0070	.7099	.8766	.5323	.9960	7
Metal	1.1660	.0216	.4924	1.6190	.3818	.9982	4
Construction Materials	1.0490	.0223	.7820	3.5870	.2180	.9857	10
Chemical	1.3190	.0585	$.2\times10^{-5}$	2.5320	.2831	.9966	10
Machinery and Equipment	1.2050	.0049	.5613	.0002	.9998	.9923	10
Light	1.3210	.0211	.4103	13.1800	.0705	.9558	10
Food	1.1430	.0230	.6045	4.2540	.1903	.9958	8
Industry	1.3020	.0319	.2223	3.9460	.2022	.9958	10
Industry 12 AFC	1.1730	.0299	.8368	12.8900	.0720	.9951	10

Table A3.1-2

Standard Errors of the CES Parameter Estimates and t Statistics (Khrushchev-Brezhnev Epoch)

Sector	γ		λ		δ		ρ	
	s	t	s	t	s	t	s	t
Fuel	.1306	7.9	.0204	.3	.3433	2.1	.4876	1.8
Metal	.0400	29.1	.0087	2.5	.0815	6.0	1.0790	1.5
Construction Material	.1062	9.9	.0080	2 8	.2776	2.8	3.021	1.2
Chemical	.0923	14.3	.0048	12.3	.1825	$.1\times10^{-4}$	$.2\times10^{5}$	$.1\times10^{-3}$
Machinery and Equipment	.2081	5.8	.0260	.2	.6072	.9	.8966	$.2\times10^{-3}$
Light	12.5900	.2	.0034	6.2	$.99\times10^{2}$	$.4\times10^{-2}$	$.1\times10^{4}$	$.1\times10^{-1}$
Food	.1349	8.4	.0029	8.0	.48	1.2	4.3	1.
Industry								
Industry 12% AFC	2.565	.5	.0014	21.6	7.9	.1	158.3	.1

With 18 degrees of freedom, the t value for both tails at the 95 percent confidence interval is 2.101, for the 90% confidence interval 1.734.

A3.2 Alternative Estimates of the Parameters of Abstract Soviet Technology: Dalton and Desai

Independent evidence on the validity of the production function estimates presented in Chapter III can be found in the works of other scholars. Tables A3.2-1 and A3.2-2 give George Dalton's and Padma Desai's estimates of the parameters of abstract technology computed utilizing the Hicks neutral variant of the CES specification. Dalton's calculations, based on the Greenslade-Wallace industrial output series 1950-1969 with conventional direct input sectoring is conceptually analogous to the estimates in Table 2.[1] Allowing for differences in sectoral nomenclature and the duration of the time series, Dalton's parametric estimates largely correspond with and confirm our findings. In every instance the sectoral elasticity of capital labor substitution is less than unity and almost always markedly so. Although on average the Hicks neutral technical progress parameter is lower than those in Table 2, this in part reflects the modest revival in Soviet productivity 1970-1973 discussed in Chapter II. Also note the aberrant character of the parameter estimates for the machinery and equipment sector which corroborates the perverse behavior indicated in Table 2. It hardly seems an exaggeration to conclude from the parallel nature of these findings that the CES specification of Soviet production characterized by extremely low capital-labor substitution values is sustained for sectors defined on the direct input convention, despite some significant differences in underlying data, sectoral coverage and the time frame of the data series.

Can it be safely deduced that this confirmation holds as well for sectors classified according to the vertically integrated, direct-plus-indirect input scheme? Desai's calculation bears on this issue. Aware of the conceptual error involved in using gross rather than net output series, Desai tried to rectify the matter by computing the residual between factor

payments including wages, profits and depreciation, and gross output which she identifies as "raw materials" or "material purchases."[2] However instead of treating the difference between primary factor cost and the gross value of output as intermediate goods, Desai chose to construe her residual as the inputed value of a third primary factor of production, raw materials. Rather than netting out intermediate inputs to obtain a consistent sectoral classification predicated on the "sector of assembly" or direct input specification, Desai opted for a scheme which resembles the vertically integrated, direct-plus-indirect factor approach. More precisely she reformulated the Hicks neutral CES specification into a three variable input model[3]

$$(A3.1) \qquad Y^{*} = \gamma e^{\lambda t}[\alpha K^{-\rho} + \beta L^{-\rho} + (1-\alpha-\beta)R^{-\rho}]^{-1/\rho}$$

where

Y^{*} = gross output

R = raw materials (including industrially produced intermediate inputs)

specifying "raw materials" as a third primary factor of production. An alternative two variable form[4]

$$(A3.2) \qquad Y = \gamma e^{\lambda t}[\alpha K^{-\rho} + (1-\delta)L^{-\rho}]^{-1/\rho}$$

where

Y = gross value added computed by deflating the agricultural and transportation components of the residual "raw materials" separately from other intermediate inputs and final product, then subtracting intermediate inputs and raw materials[5]

was also tested but since both raw materials and intermediate inputs are netted out after being separately deflated, equation A3.2 pertains exclusively to the intrasectoral output-input specification and as such does not concern us here.

Even equation A3.1 which treats "raw materials" purchased from other sectors as a value added component of the purchasing sector is not fully comparable with the input-output value added scheme previously set forth in Chapter II. There all intermediate inputs, including raw materials, were expressed in terms of the capital and labor embodied in their production elsewhere in the economy not as a third primary factor of production. Instead of computing the direct-plus-indirect value added of intermediate goods, Desai's method lumps together raw materials, transportation services and <u>industrial intermediate inputs</u> into a homogeneous factor of production the value of which cannot be reduced to their marginal capital and labor costs of production. This leads to the very peculiar result that although the output of every sector depends functionally on capital, labor and raw materials-cum-intermediate inputs, the intermediate input component of raw materials is treated as if neither capital nor labor were required for its production.

Whatever one may think about the analytical merit of such an inconsistent specification, with its idiosyncratic definition of raw materials, equation A3.1 is conceptually related to the vertically integrated classification of the value added production process and therefore provides a bench mark for guaging the reliability of the findings in Table 1. Desai's results are presented in Table A3.2-2. They were computed from a small sample, 1955-1971, affording only 11 degrees of freedom, so that even if everything else were compatible, some variation in our results should be anticipated. Despite these numerous caveats, as with Dalton's estimates, Desai's findings are similar to those in Tables 1 and 2. Most striking of course is the low elasticity of factor substitution exhibited for both equations A3.1 and A3.2. While it would be rash to press evidence as qualified as this too far, it does demonstrate the robustness of the low capital-labor substitution parameter in the face of extremely diverse specifications.

Table A3.2-1

Dalton's CES Estimates
Using the Direct Input Classification,
Labor in Man Years, Observations 1950-1969

Sector	γ	λ	δ	ρ	σ	R^2
Ferrous Metals	.7143	.0303	.2775	2.2457	.3081	.999
Construction Materials	.7420	.0244	.4615	.4914	.6705	.999
Chemicals	.7132	.0235	.5797	11.3916	.0807	.992
Machinery and Equipment	.9505	0	.9560	10.9332	.0838	.987
Light	.8009	.0196	.2470	5.6534	.1503	.998
Food	.8810	.0130	.3555	3.7893	.2088	.996
Industry	.8538	.0123	.5414	2.1817	.3143	.998

Table A3.2-2

Desai's CES Estimates
Labor in Man Years, Observations 1955-1971

Sector	γ	λ	δ	α	β	ρ	σ	R^2
Aggregate Industry (equation A3.1)	*	0.0408		0.0210	.6798	3.4033	0.2771	.9994
Aggregate Industry (equation A3.2)	*	0.0101	0.8930			4.9312	0.1686	.9913

*Values for the scale parameter were not provided.

A3.3 The Marginal Productivity of Capital

The marginal productivity of capital implied by the income shares presented in Tables 4 and 5 is so low that some may wonder about its plausibility. Can the marginal productivity of Soviet capital really approach zero? The answer to this rhetorical question is affirmative, if the ruling conventions of abstract technology are perceived in the proper perspective. Capital in production function analysis is regarded as a homogeneous, non-quality differentiated input. If the elasticity of factor substitution is less than unity and capital increases more rapidly than labor, increased capital intensity must result in declining marginal capital productivity. That is, if an augmented supply of identical machines is distributed to a fix supply of workers, output at the marginal must decline. This however does not preclude the possibility that as the stock of capital rises, the average quality of capital might increase with it. Such an improvement in capital quality would imply that capital productivity is certainly positive, but within the conventions of abstract technology capital's contribution would be imputed to technical progress. Only by ascertaining directly the relative shares of embodied and disembodied technical progress could we discover the precise magnitude of the capital contribution. Thus, the ostensible implausibility of zero marginal capital productivity depends in large part on the special meaning imparted to the concept as the marginal return to a homogeneous and increasingly abundant factor of production. Once this is recognized then the extremely low elasticities exhibited in Tables 1 and 2 do not really imply behavior any more perverse than those reported by Weitzman.[6]

For example, if the capital productivity trend underlying Weitzman's income share statistics is extrapolated to 1984, the marginal capital

productivity becomes insignificant with the capital income share approaching 10%, compared to 86% in 1950. This decline is less precipitous than the decline implied in Tables 4 and 5, but the long run implications are similar. On either interpretation the future course of Soviet growth depends more on technical progress than on capital intensification.

A3.4 The Agricultural Cycle

An implicit assumption underlying production function analysis is that fluctuations in intermediate inputs do not distort the observed relationship between output and primary inputs by artificially constraining production. One sector of the Soviet economy where this implicit assumption might be dangerously misleading is the Food industry where output depends heavily on notoriously volatile agricultural inputs. To test the sensitivity of our regression results to the impact of agricultural fluctuations, the parameters of abstract technology were reestimated with an adjusted Food output series.

The cyclical influence of agricultural fluctuations on Food output was removed by smoothing the output series for the periods 1950-58, 1959-63, 1964-67, 1968-73. This was achieved by taking the implied compound growth rate of final Food output for each period and interpolating.[7]

Using the Hicks neutral CES functional specification the parameters of abstract technology were reestimated respectively for the direct and direct-plus-indirect input classifications. Table A3.4-1 reports these estimates confirming the CES character of Food production, with low capital-labor substitution ratios, and indicating that agricultural fluctuations have not significantly distorted the results presented in Tables 3.1 and 3.2.

Table A3.4-1

CES Estimates for the Food Sector
Adjusted for Agricultural Fluctuations

Factor Classification	γ	λ	δ	ρ	σ	R^2	Iterations
1. Direct-Plus-Indirect	.9873	.0207	.6059	6.0590	.1417	.9991	6
2. Direct	.9669	.0257	.8705	6.3810	.1355	.9980	6

Notes to Appendix 3

1. George Dalton, unpublished manucript provided by Donald Green.

2. Padma Desai, "Soviet Industrial Production: Estimates of Gross Outputs by Branches and Groups," Bulletin of the Oxford University Institute of Statistics, forthcoming, manuscript, p. 3.

3. Padma Desai, "The Production Function and Technical Change in Postwar Soviet Industry: A Reexamination," unpublished manuscript, p. 13.

4. Ibid, p. 14

5. Ibid, p. 27 and pp. 28-35.

6. Weitzman, op. cit., p. 682. Notice that it took 13 years for Soviet income share to reach the proportions prevailing in 1962. Projecting this time span forward from 1969 when the 1962 proportions are reversed suggests that the capital income share will reach 14% in 1982.

7. An alternative method of smoothing the output series would have been to compute total intra period output growth and then calculate the compound rate implied by the actual value of produced output. This can be achieved by forming the ratio of actual output growth to the implied compound output volume

$$\text{(1n)} \qquad \lambda = \frac{\int_0^n (Y_i - Y_0)}{\int_0^n (1+r)^{n-1}(Y_i - Y_0)}$$

and adjusting the terminal output value

$$\text{(2n)} \qquad Y_n^* = \lambda Y_n$$

to permit the computation of a new smoothed output series. A test of the alternative method for the period 1950-1973 affected the growth rate by 0.15%, so that the potential distortionary effect of omitted real output can be ignored.

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Chapter IV

THE CONTRIBUTION OF TECHNOLOGY TRANSFER TO POSTWAR SOVIET ECONOMIC GROWTH

I. Introduction

In the preceding chapters an attempt has been made to scrupulously investigate the character of abstract Soviet industrial technology, identifying the analytic and econometric limitations of production function analysis, while stressing the robustness of the CES values estimated. In this chapter the evidence gathered on the abstract character of Soviet industrial technology is applied to the assessment of technology transfer, in order to discover what share of measured Soviet industrial growth is imputable to borrowed technology from the West. Although this subject has been widely discussed of late, little is really known about the magnitude the contribution technology transfer has made to Soviet growth.[1] Our ignorance is not accidental. The problem is formidable, both conceptually and econometrically, and does not lend itself readily to incisive simplification. The analysis that follows therefore is conceived not as a complete and definitive assessment of technology transfer, but rather as a step forward in coming to grips analytically and quantitatively with a highly intractable problem.

II. Abstract Technology and Technology Transfer

The parameters of abstract technology estimated in Chapter III contribute two essential pieces to the puzzle of technology transfer, First, assuming Hicks neutral technical progress with homogeneous non-quality adjusted inputs, the CES specification implies that the entire contribution of technology to aggregate industrial growth from both domestic and foreign

sources was approximately 3% per annum, 1950 to 1973. Insofar as net industrial capital imports were positive, a further but relatively negligible growth increment is imputable to the enlargement of the domestic stock of reproducible capital.[2] Second, Hicks neutral technical progress has not been uniform across sectors. Certain branches of industry such as chemicals exhibit high rates of technological growth, while others like fuels are laggard.

Taken together these statistics establish the magnitude of aggregate postwar Soviet technological progress and illuminate its sectoral character. For example, if the Soviet GNP in 1973 were approximately 700 billion current U.S. dollars[3] and 40% of this amount were comprised of industrial output other than construction, communication, trade, transportation, agriculture and services,[4] then it can be deduced that technological progress in industry contributed roughly 8 billion dollars to the national product. Depending on the precise parametric values of technical progress in the rest of the economy, total technological progress would be more or less than proportional to the industrial rate. If for didactic purposes we suppose strict proportionality, then the aggregate contribution of technical progress to Soviet growth would rise to 21 billion dollars.

This figure constitutes a conservative upper limit both for the magnitude of technical progress and technology transfer were one to presume that all technical progress were foreign in origin. However remembering that measured productivity growth in services is nominal in all countries, that it is slight in construction and that technical progress in Soviet agriculture has been modest at best, it must be further inferred that the aggregate value of technological progress is likely to be closer to 8 than to 21 billion dollars, or choosing the mean, approximately 2% of GNP.

This estimate, crude as it surely is, establishes a rough order of magnitude which bounds the domain of plausible speculation and enables us to proceed systematically in assessing the contribution foreign technology has made to technical progress. As will soon be apparent, the estimates of sectoral technology presented in Chapter III provide valuable evidence for distinguishing foreign from domestic sources of growth. Before turning to this material however, it will be useful to consider the problems entailed in estimating the contribution of technology transfer at a more formal level.

III. Intertemporal Optimality and the Pure Theory of Technology Transfer

In trying to acquire a realistic appreciation of the contribution technology transfer may have made to postwar Soviet technical progress a standard of achievement needs to be established in order to clarify how the pragmatic policies of Soviet planners may have approximated some comprehensible ideal. By analogy with the Fisherian variant of intertemporal perfect competition, such a standard can be easily developed for the never-never world of computopia where optimal mixes and volumes of goods and services are produced over a specified multiperiod time frame, subject to a general convex program, given a planners' objective function. Suppose that Soviet planners know society's rate of time preference and the mix of future goods and services that would maximize social welfare given concave opportunity cost schedules for all goods produced in the future with diverse technologies, as well as the amount of foregone current consumption necessitated by investment cum research and development. Armed with this information planners could in principle calculate a globally efficient, intertemporal social welfare optimum that took explicit account of the future consumption alternatives potentially facilitated by current investment embodying diverse technologies.

The intuitive structure of the problem is best grasped with the aid of Irving Fisher's felicitous concept, "trading with the future." If it is presumed that technical progress is not a free good, then the benefits which flow from advances in technology can only be achieved by devoting present resources to research and development and the production of new investors' durables embodying state of the arts technology. Since such allocations necessarily diminish current consumption, technology intensive investment can be conceived of as the cost or sacrifice in terms of current consumption required so that society can acquire an augmented stream of consumers' goods in the future. When society decides to make this sacrifice, it in effect "trades with the future," by foregoing current consumption in exchange for the provision of deferred goods and services.

The precise magnitude of this exchange, the level of investment, is determined by society's rate of time preference in conjunction with the opportunity costs governing the transformation of present consumers' and investors' goods. At the optimal investment point, the marginal rates of transformation and substitution (time preference) for present and future goods will be equal and inversely proportional to relative intertemporal prices or the real rate of interest. Since intertemporal general equilibrium further implies that the rate of return at the margin be the same for all types of investment, risk aside, a necessary corollary of the Fisherian conception is that the present discounted marginal utility of all future consumers' goods be precisely equal to the marginal utility of present consumers' goods. When this occurs no further opportunities for trading with the future remain and computopic intertemporal general equilibrium is attained.

While the assumptions required by computopic general equilibrium are even more implausible than those underlying perfect competition,

methodologically they provide a hypothetical criteria for choosing optimal technologies both in the present and the future, given the epistemologically dubious supposition that planners could actually ascertain the social utility opportunity costs of trading with the future. Reference here is to Irving Fisher's principle of the "rate of return over cost" made famous by Keynes who equated the Fisherian concept with his own notion of the marginal efficiency of investment.[5]

The rate of return over cost is a measure of the differential present cost or sacrifice of two or more investment options needed to obtain a differential future return or income.[6] It is computed by discovering the discount rate that sets the present value of two alternative income streams equal. By selecting any particular investment option as the standard all investment opportunities can be ranked in terms of their rate of return over cost. In every case intertemporal utility is maximized by choosing the investment option with the highest rate of return over cost, provided that it exceeds the interest rate. Just as in the Keynesian marginal efficacy of investment formula, after the most profitable alternative is selected, investment does not terminate but continues until all profitable options, those with yields in excess of the interest rate, are exhausted. At the point where the economywide rate of return over cost equals the interest rate, the present value of all investment alternatives at the marginal are equal, and therefore in a generalized Paretian sense it becomes impossible to exchange any good in either the present or the future so that one person's utility could be increased without necessarily diminishing the utility of another individual.

Of course the very fact that the present value of an asset might exceed its production cost implies a temporary divergence from intertemporal general

IV. Principles Governing the Rate of Return Over Cost Between Domestic and Foreign Technology

Once it is perceived that technology transfer should be optimized rather than maximized, the principles determining the optimal transfer level need to be explicated. Fundamental here are the prevailing states of technological attainment, differential rates of domestic and foreign scientific progress, associated development costs, implementation costs and changes in the pattern of societal demand.

Differential levels of scientific achievement establish the potential for profitable technology transfer. They imply that other things being equal, per capita productivity in the backward economy can be substantially increased through the acquisition of advanced foreign technology. The existence of a technology gap however does not decide either the short or the long course of technology borrowing. What really matters for a centrally planned economy is the rate of return over cost between domestic and foreign investment alternatives. Differences in scientific achievement may determine the magnitude of relative future returns, but they do not necessarily govern relative present cost.

What can be said a priori about costs? Will they be positively or negatively correlated with economic development? Cost, as it is always understood in general equilibrium theory, means the opportunity cost of employing scarce resources in diverse uses. Where choice concerns domestic and foreign investment alternatives, the opportunity cost that confront the investor or planner refers unambiguously to the domestic acquisition of either technology measured in domestic resources. Since foreign technology must be purchased with exports this implies that the resources embodied in those exports should be interpreted as the true domestic acquisition cost, whatever the actual production cost abroad valued in foreign factor inputs.

equilibrium. This however does not pose any fundamental problem for Fisher who argues that as tastes change or new inventions arise temporary divergences from general equilibrium occur which are resolved dynamically through capital gains and losses in the asset values of current stocks and through changes in the produced mix of present and future goods and services. In the particular case of investment this is achieved by employing the economywide rate of interest representing society's best collective estimate of the sustainable equilibrium rate of return as a standard for evaluating the relative merit of investment opportunities brought about by unanticipated changes in demand.

Conventionally this presumes that all relative prices adjust less quickly than the interest rate, circumscribed as they are by short term supply elasticities, so that differential profit opportunities exist, at least temporarily. Nuances aside, however, the Fisherian intertemporal utility optimization approach combined with the practical rate of return over cost norm constitutes a compelling hypothetical standard for assessing investment merit under any economic system.

The concept of rate of return over cost is perfectly general in another important sense. It makes no difference whether the investment options embody foreign or domestic technology. In principle real technology transfer should be determined solely by the rate of return over cost. So long as foreign technology affords a higher discounted net return per ruble, the foreign option should be preferred providing as always that its discounted present value exceeds its domestic acquisition cost.

Once this point is grasped, the relationship between present cost and future return is easily understood. If increasing costs prevail in all industries, as exports rise so will their domestic factor cost at the margin. As a consequence, gains from the differential future return derived through the acquisition of foreign technology will be progressively offset by the increased marginal domestic factor cost of exports. So long as the rate of return over cost exceeds the interest rate technology should still be imported. But when the marginal export cost ultimately equilibrates the rate of return over cost with the interest rate, borrowing should cease, even though a sizeable technology gap might persist.

From a comparative static viewpoint this technology gap need not be perpetual. Each year the backward economy imports more foreign capital durables until eventually (ceteris paribus) the average level of embodied technology equalizes on a worldwide scale. But is the rate of technology transfer really fixed by import volumes? Can't foreign technology be copied domestically enabling the substitution of cheap domestic for expensive foreign capital? Yes, but the same Fisherian rule applies here as elsewhere. The rate of future return over present cost between the domestic copy and the foreign original measured against the interest rate determines the economic merit of duplicating foreign technology. Moreover, just as the gains from imported technology depend on the volume of exports, so the benefit of domestic duplication diminishes as resources are diverted from exports to the production of import substitutes. Thus, even the supplementary advantage of duplication are strictly circumscribed, such that the optimal rate of direct-plus-indirect technological borrowing is governed by the rate of return over cost for all investment options regardless of origin.

In the main the cost functions that affect the relevant rates of return over cost should reflect the conventional determinants of production. Certain aspects of the cost of technology transfer however require special consideration. Even under the most fortuitous circumstances, it may be more difficult to absorb new technologies in some parts of the economy than others. The time profile over which a particular innovation is absorbed is known as diffusion. Diffusion rates vary widely from product to product and perhaps by national origin as well. If non-indigenous technologies have been designed for productive environments which are not congruent with the operational procedures of the borrowing nation, then it could well be that the diffusion rate associated with foreign capital is slower than domestic capital, thereby reducing the potential advantage of technology transfer. If an attempt is made to mitigate these costs by modifying imported capital goods or by redesigning foreign technologies for domestic uses, real costs will also be entailed. Without hazarding a guess as to what their relative magnitude might be, it is easy to see that even in technologically backward countries the supplementary cost of production associated with diffusion, modification and redesign could substantially reduce the magnitude of profitable technology transfer. Indeed the burden of these costs explain to some degree why many development theorists believe that backward nations would profit more from the importation of simple technologies as opposed to those that embody the state of the art.[7]

Supplementary production costs affect technology transfer in another way as well. Until now, our analysis has assumed that the level of domestic and scientific achievement was eternally fixed. How does scientific progress affect technology transfer? In the simplist case where everything is held ceteris paribus, the principle consequence of scientific progress is

enhanced worldwide productivity. This is true whether the locus of new technology is in the advanced or backward nations on the supposition that technology once developed enters the public realm and by hook or crook can be implemented anywhere. Secret technologies aside then, scientific progress can only alter the absolute magnitude technology gap if international rates of diffusion vary and supplementary costs are significant, disregarding differences in taste. Making the absolute magnitude of the technology gap hinge on diffusion and supplementary costs of borrowing, sets the deeper problem of Soviet growth in an illuminating perspective. Instead of research and development serving as the ultimate arbiter of economic power, attention is directed to the adaptive and implementive capacities of alternative economic systems. More specifically the relative technological position of the USSR and the US depends fundamentally on whether the workably competitive market is superior or inferior to the centrally administrative planning system in efficiently diffusing technology throughout the economy.

Efficient diffusion notice does not necessarily mean rapid diffusion. Long term relative economic productivity hinges on selecting the proper technology mix in the requisite volumes, not on maximizing the diffusion rate on certain priority innovations. The principle of maximum present value not maximum diffusion must prevail.

Without conducting an elaborate analysis of the comparative merit of the Soviet and American process of diffusion and implementation it is probably not too incautious to suppose that the Russians are at a disadvantage both in stimulating the pace of diffusion and insuring that the appropriate technologies are adopted. As regards the rate of diffusion, it is well known that despite much organizational experimentation the Soviets have not been successful in devising a satisfactory incentive scheme to

promote rapid diffusion.[8] Likewise, although the Typical Method utilized by the Soviets for selecting alternatives is predicated on the logic of opportunity costs,[9] and in form resembles Fisher's rate of return over costs, due both to notorious limitations of Soviet price formation and idiosyncrasies of conceptualization,[10] established investment criteria cannot accurately discriminate the appropriate composition and volumes of imported technologies.

This negative appraisal although ostensibly inconsistent with the Soviet record of economic progress, really is not. The administrative shortcomings of technology transfer policy during the industrialization drive and on into the late 1950's were in part masked by the fact that the marginal effect of new technologies tended to be greater in backward than advanced countries. For example if US capital were twice as productive as Soviet capital, an innovation which increased American productivity 10% would ceteris paribus increase Russian productivity 20%, thus diminishing the relative magnitude of the technology gap. For several decades, the rate of technical progress achieved by the Soviets exceeded that of the US, resulting in an obvious closing of the relative technology gap. But in recent years the advantages of backwardness have been curtailed, and the inefficiencies of the Soviet system of technological diffusion have manifested themselves. If the thrust of the foregoing analysis is not misdirected, the advantages of backwardness are not likely to countervail the deficiencies incumbent in the Soviet system of centralized administrative planning. The recent retardation in the rates of Soviet growth and technical progress may well become an enduring and distinctive aspect of the post Stalinist model of Soviet economic development.

V. The Cyclical Pattern of Technology Transfer

Fisherian theory, even though it has inherited the dynamic Marshallian quantity adjustment and Walrasian price adjustment mechanisms from general equilibrium analysis, is still static in an historical sense to the extent that it fails to endogenize institutional and cultural factors. Therefore in assessing the long term pattern of technology transfer one might anticipate that the smooth and efficiently continuous character of technological borrowing suggested by Fisherian theory would turn out to be a more complex phenomenon in practice. Indeed, this has been the case. For example Alexander Gershenkron has contended that the importation of foreign technology from the time of Peter the Great through the Stalinist industrialization drive has been spasmodic but predictable.[11] The argument casts Russian society as a culture torn between a desire for self-protective isolation and the acquisition of the technological advantages of the West. So long as the costs of insularity were low, as was the case whenever Russia was expanding East and South, Slavic orthodoxies and institutions held sway. Cultural and technological borrowing from the West was minimal. However, when a military defeat at the hands of the Western powers, or the imminent threat of military disaster suddenly brought home the accumulated cost of isolationism, the Westernizing tendency became ascendent and within an historically brief compass of time, Western technology was imported on a prodigious scale.

Historical forces therefore seem to have imparted a boom, bust cyclical pattern to the acquisition of foreign technology not envisioned by the Fisherian conceptualization. But are there any grounds for supposing that this long term pattern has persisted into the postwar period, after the consolidation of Soviet industrial power, after the repudiation of

"Socialism in One Country," after the achievement of Superpower status that pits the Russian East against the American West so clearly that the threat of technological stagnation cannot be evaded? One would have thought that the institutionalization of technology and growth in the USSR would have persuaded the Soviets that the fastest and best way to overtake the West was on the Fisher Turnpike.

Donald Green and Herbert Levine have recently evinced an opposing view, arguing that the Gershenkron hypothesis should be extended to the analysis of postwar trends in Soviet technology transfer.[12] Noticing a major discontinuity in the level of capital durables imported from the West in the late 1960's, after a period of flagging domestic growth, Green-Levine suggested that the Soviets have returned to their time tested strategy of massively borrowing foreign technology on a short term basis in order to overcome their perceived technological backwardness.

Although the Green-Levine hypothesis accords more or less with the facts, this of course does not decide the issue which depends on one's conception of continuity in history. However, without seeking to prejudge the issue, in the context of the present study it is interesting to observe that a purely Fisherian interpretation can be given to the postwar pattern of Soviet technological borrowing which avoids the pitfalls of Historicism.[13] All that is required is to recognize that in centrally administered economy where the costs of decision making are minimized by selecting a group of high priority foreign technology intensive capital imports from among the vast and changing array of importable technologies, the rate of future return over present cost is apt to jump discontinuously as slow rates of diffusion for an unrevised set of priority technologies causes a gap to emerge between the productivity of new and old technologies. Put somewhat

differently, in the absence of general competitive pressures, the decision to import particular technologies, rather than being constantly revised, remains ossified for protracted periods until the opportunity cost losses become so great and apparent according to the Typical Method, that a crash program is instituted to make up for lost time. Initially, a slow rate of diffusion would be beneficial because it would save the Soviets from over investing in obsolete technologies. However this compensatory advantage is not likely to be decisive if slow diffusion rates allow the gap between implemented and potentially more productive technologies to reemerge. Unless the Soviets find an administrative method of replicating market forces which insure that new technologies are perpetually monitored and adopted wherever warranted by the rate of return over cost, the pattern of foreign technology transfer is likely to be strongly cyclical with bursts of foreign capital importation, contrasted by periods in which domestic energies are focused on diffusion and absorption of acquired techniques.

Whether the cyclical pattern conjectured above will really prevail is hard to foresee, for it must not be forgotten that Soviet relations with Eastern Europe constrain their foreign trade options. Be this as it may however, it is worthwhile to note that recent Soviet technology transfer policy can be plausibly explained by purely economic considerations without recourse to alluring, but more tenuous historicist explication.

VI. The Absolute Magnitude of Technology Transfer

In surveying the pure theory of technology transfer two fundamental quantitative issues have emerged as the central factors determining the size and scope of Soviet gains from technology transfer:

1. The dollar value of technology transfer
2. The technology gap.

Neither can be quantified with exactitude. Valid assessment however is not entirely outside our grasp, even though the problems entailed are formidable. For example, the absolute value of technology transfer requires not only that the growth effects of technical progress be isolated, but it also necessitates distinguishing foreign from domestic sources of technical progress. This encompasses all sources of Hicks neutral domestic technical progress including increases in labor skill and knowledge (education) not captured by the labor input series which makes no allowance for qualitative change. Likewise, the technology gap cannot be viewed statically. It is governed by institutional idiosyncrasies of Soviet investment decision making, the diffusion rate, the transfer cycle and the efficiency of the Soviet technology transfer program measured in terms of potential rates of future return over present cost. In this section attention is focused on the magnitude of technology transfer. The problem of the technology gap is deferred to section VII.

Any calculation of the contribution made by foreign technology to aggregate technical progress must begin with a prior judgment on the appropriate criterion for distinguishing foreign from domestic technologies. Invention or even innovation might be such a norm. But this choice leads to difficulties. By almost any authority's estimate, relatively few major inventions originated in the East. Even the Hungarian economist Janos Kornai in his recent book, Anti-Equilibrium cites statistics which demonstrate that only five percent of the "revolutionary" technologies developed in the twentieth century can be attributed to the "Socialist Bloc" and half of these were simultaneously, but independently developed in the West.[14] Taken literally this implies that most operational Soviet technologies were at

one time or another imported from the West so that almost all the growth imputed to technology transfer should be treated as foreign.

Fisherian analysis however suggests that such an intepretation is extreme. Throughout the postwar period, even in years when the volume of imported technology intensive Western capital goods was high, the share of Western capital durables in total new capital formation rarely reached 4%.[15] If construction durables are omitted from new capital formation, which they should not be, the contribution of Western technology could perhaps even be increased to 8%. Adding to this magnitude all disembodied transfers in the form of patents and licensing agreements, 10% could be posited as a speculative upper limit of the annual direct contribution of Western technology to Soviet growth.

This estimate of course omits the benefits from "domesticating" Western technology through duplication and adaptation. As was argued earlier, domestication is not a costless process. Foreign technologies designed for different organizational environments will usually require substantial modification or redesign if they are to have an impact commensurate with their potential. Modification and redesign while not obviously "revolutionary innovations" should properly be perceived as the dominant contribution of Soviet science and engineering to technical progress. In this regard it is useful to remember that direct technology transfer is a once and for all event, at least in the form of imported capital durables. Modification and redesign however are ongoing processes. They are applicable to the entire historical stock of imported technologies, and in their own inglorious way, must in the aggregate make a substantial contribution to technical progress. If this were not the case why would the Soviet stock of scientists and engineers continue to grow year after year, when in absolute terms their numbers are already extremely high by world standards? Support for this

line of argument can be found moreover in the military sector. The Soviets did not invent jet planes, rockets, hydrogen bombs, tanks or submarines. Their weaponry nonetheless is competitive with Western counterparts and in many ways novel. Were we to assess the technological attainment of Soviet science and industry solely on the basis of generic classification, the innovative potential of Soviet military systems would be greatly understated. Reasoning by analogy, it is probably unwarranted to infer that the domestic Soviet contribution to civilian technological progress is negligible because most "revolutionary technologies" have been invented in the West. Moreover, the shortcomings of the Soviet incentive system should not be forgotten. Duplication without modification or redesign may be extremely costly to Soviet enterprises given resources on hand or easily acquired. Domestication of foreign technology implies that Soviet enterprise directors can be persuaded to disrupt their production schedule in order to retool according to foreign specifications. As the literature suggests, it is not too difficult to suppose that the opposite is true, and that enterprise managers when forced to innovate, strive to minimize "private" enterprise loss by choosing those technologies that modify existing procedures as little as possible. All this indicates that contrary to the evidence based on nominal source of invention, technical progress must largely be attributed to domestic Soviet science and engineering.

One countervailing factor however requires explicit consideration. Perhaps the magnitude of the relative marginal products of Soviet and foreign technologies are so disparate, that even the small direct Western input supervenes the domestic effort. Donald Green and Marc Jarsulic have recently suggested that this is so.[16] Using a three factor Cobb-Douglas model without an exogenous technology term, they show that the marginal productivity

of foreign capital, assuming "a constant effort of internalization" is as much as 15 to 17 times the domestic marginal product. While it can be hardly doubted on Fisherian principles that the rate of future return over present cost justifies the importation of Western durables, the rates of return implied by these calculations appears excessive given the prevailing stage of Soviet industrialization.[17] It seems incomprehensible for example that marginal capital productivity in the priority machinery and equipment sector could be one seventh the foreign level. One would have thought that differences in capital productivity on the order suggested by Bergson, namely 60% would have been much nearer the mark.[18]

This however is not the place to adjudicate the disparity between these estimates. What is significant for our purposes is the fact that unless the marginal productivity of imported capital is three to four hundred percent greater than its domestic counterpart, the contribution of foreign technology to aggregate Soviet technical progress is unlikely to reach 50%.[19] I myself would guess that all things considered 25% would be a high estimate of the foreign contribution, including domestically duplicated foreign technology. This however must be treated merely as an informed guess because of the imponderables involved.

Suppose though for argument sake a figure of 33% is designated as the foreign contribution. Remembering that aggregate technical progress was roughly 2% or 14 billion dollars in 1975, the foreign contribution might be set crudely at 5 billion dollars. But this figure omits the contribution of improvements in labor skill and knowledge associated with education. According to Denison this is a major source of economic growth, which has been of necessity subsumed in our measure of technical progress.[20] Depending on how this source of growth is factored into the estimate, the true

contribution of foreign technology could range anywhere from one to four billion dollars. Accepting 4 billion as an extremum, it is now easy to see that technology transfer cannot reasonably contribute more than 0.6% per annum to the Soviet growth rate in the postwar period, and the true figure may be considerably less, on the order of 0.2%.

At first blush, this is a startling result. Has past Soviet growth been largely attributable to internal factors? Looking back at the literature on the Thirties, it is difficult to obtain a precise impression. What information is readily available however suggests that achieved rates of technical progress under the early Five Year Plans was not particularly spectacular.[21] If this characterization is accurate for a period when the Soviet economy was genuinely backwards by Western standards, it should be anticipated that the gains from technology transfer would diminish as a share of GNP as per capita output and productivity converged toward the world level. However profound the impact of technology transfer may have been in Petrine Russia or in the post Crimean period under Alexanders II and III and Nicholas II, the experience of the twentieth century may well have been less dramatic, especially after the Second World War.[22]

It should be realized moreover that even one half of one percent is equivalent to one fourth of total annual Soviet technical progress. In absolute terms this is not an insignificant amount. The four billion dollars which we conjecture is imputable to foreign technology annually represents a sum greater than the entire Soviet lend lease debt to the United States. Thus the nominally small fractional value of the GNP attributed to technology transfer should not be taken to mean that foreign technology constitutes an unimportant source of Soviet growth. Six tenths of one percent after all equals more than 10% of annual Soviet growth including the effect of increased capital and labor inputs.

Before leaving this subject let us briefly consider the maximum impact technology transfer could conceivably have on Soviet growth if the rate of technological borrowing were greatly increased. Suppose that the contribution of each unit of foreign capital to total technical progress were approximately three times the domestic contribution, which would be the case if after all adjustments the foreign share were 33% and technical progress advanced 1.6% per annum.[23] Given these assumptions each unit of foreign capital would contribute 3% and each unit of domestic capital 1% towards aggregate technical progress net of the 0.4% imputed to advances in labor skill. This implies that if the Soviets managed to switch entirely to foreign technology, technical progress would rise from 1.6% to 3.0%. Thus in the limiting case where technology transfer was complete, Soviet growth would rise only 1.4% per annum above current levels. Were the Soviets merely to double both their direct (capital imports plus licenses) and their indirect acquisition (duplication of foreign technology) of foreign technology, the net effect on the growth rate would be only .7%.[24] While the nature of these calculations precludes accepting .7% as a definite and realistic upper bound, it appears that the probable magnitude of potential Soviet gains from technology transfer will not by itself restore the rate of aggregate Soviet economic growth to the halcyon levels of the 1950's.

VII. The Efficiency of Technology Transfer and the Technology Gap

The long term significance of technology transfer from the developed West to the Soviet Union hinges not only on the dollar value of transfer induced domestic economic growth, but on the overall efficiency of the transfer process itself. The political and economic meaning of technology transfer inheres not just in the magnitude of the Soviet benefit, but in the relationship of that benefit to the rate of economic progress in the West.

If the Soviets are efficient at the transfer game, Fisherian analysis suggests that they should be successful in closing all but a small portion of the technology gap. If they are inefficient, if the benefit from transfer is hardly greater than the domestic rate of technical progress then the gap may close, open or remain unchanged depending on the domestic rate of scientific progress and innovation. Thus in addition to estimating the magnitude of the foreign contribution to Soviet growth, a supplementary appraisal of the efficiency of technology transfer and its implications for long term relative East-West economic development is clearly germane to our inquiry.

A good point of departure for evaluating the efficiency of Soviet technology transfer is the foreign share of neutral technical progress discussed in section VI. Does this share reflect the full accrual of the potential gain from technology transfer, given prevailing import levels and diffusion rates? Or, could the Soviets have increased their growth rate by more effectively absorbing the productive potential inherent in imported technologies?

A comprehensive answer to these questions would require engineering knowledge of the productive capabilities of foreign and domestic Soviet capital goods. Interesting results can be obtained however without determining the real difference between the actual and potential economic benefit by posing the technology transfer question in a special way. As a fundamental hypothesis, let us postulate that if technology transfer is efficient there should be a demonstrable and statistically significant correlation between the magnitude of the technology transfer and the volume of output it engenders. Observed correlations may be imperfect if the basic specification is incomplete, but in principle a definite and systematic relationship

between technology transfer and output must exist if it is to be supposed that foreign capital has had an impact on Soviet growth different from domestic capital. Put somewhat more formally, the efficacy of technology transfer should be tested with a null hypothesis which stipulates that there is no empirical difference between the effect Soviet and foreign capital durables have on technical progress. Casting the null hypothesis this way has a double virture. First it deals directly with the problem of the relative productivity of imported capital, but second and more interestingly for our purposes, it bears on the crucial issue of how successfully the Soviets are in utilizing foreign technology after it is acquired. This is the crux of the efficiency issue. For if the null hypothesis is validated then technology transfer to the Soviet Union cannot possibly be efficient, because such a result would contradict all known indicators of relative productivity whether the measure be "revolutionary inventions" or comparative factor productivity analysis.

The test of the efficiency of technology transfer therefore depends on whether known, superior Western technologies systematically augment Soviet growth more than domestic technologies. If the effects of Western technologies are statistically indistinguishable from domestic Soviet technologies, then it must be inferred that actual gains from technology transfer shortfall potential benefits.[25] Tables 1 and 2 provide a first glimpse of the quantitative problem at hand. Table 1 compares trends in machinery imports from the world at large for diverse years with corresponding intraperiod average annual growth rates for the importing sectors. Machinery imports are defined consistently with the rest of this study and exclude capital durables imported for non industrial use, construction, trade, transportation communication, services and agriculture.

Table 1

Soviet Machinery Imports and the Postwar Growth
Of Industrial Producers' Goods 1950-1973

USSR-WORLD

Period	(1) $\sum_{i=1}^{n} M_i / \sum_{i=1}^{n} K_i$	(2)	(3) $\Delta Y/\Delta t$
Quinquennial			
1950-54	0.80	100	13.6
1955-59	0.79	98	9.8
1960-64	1.09	136	7.6
1965-69	0.92	115	7.2
1970-73	1.03	128	6.0
Historical			
1950-58	0.77	100	14.2
1959-63	1.10	143	8.8
1964-67	0.89	116	7.3
1968-73	1.02	133	6.5

1. Ratio of Soviet machinery imports (M) from all countries, excluding transportation, communication, trade, agriculture and construction durables, to the domestic industrial capital stock (K). Import data taken from Vneshniaia Torgovl'ia SSSR, various handbooks. Capital data taken from the 1966 Soviet I-O table and serialized with the Greenslade-Wallace index. The total value of machinery imports and industrial capital for each period is summed separately and divided to form the M/K ratio. Note if annual industrial investment is 10% of industrial capital, machinery imports represent roughly 10% of investment.

2. Index of column 1, 1950-54 = 100 (quinquennial), 1950-58 = 100 (historical).

3. Average annual rate of industrial growth. Industry is defined on the same basis as machinery imports.

Table 2

Soviet Machinery Imports from the West
And the Postwar Growth of Industrial Producers' Goods: 1955-1973

USSR-WEST

Period	(1) $\sum_{i=1}^{n} M_i / \sum_{i=1}^{n} K_i$	(2)	(3) $\Delta Y/\Delta t$
<u>Quinquennial</u>			
1950-54			
1955-59	0.12	100	9.8
1960-64	0.29	242	7.6
1965-69	0.27	225	7.2
1970-73	0.33	275	6.0
<u>Historical</u>			
1955-58	0.10	100	14.2
1959-63	0.29	290	8.8
1964-67	0.20	200	7.3
1968-73	0.34	340	6.5

1. Ratio of Soviet machinery imports (M) from the West, excluding transportation, communication, trade, agriculture and construction durables to the domestic industrial capital stock (K). Note if investment is 10% of industrial capital, machinery imports from the West represent roughly 3% of industrial investment.

2. Index of column 1, 1955-59 = 100 (quinquennial), 1955-58 = 100 (historical).

3. Average annual rate of industrial growth. Industrial output excludes transportation, communication, trade, construction, agriculture and services.

The variable, $(\sum_{i=1}^{n} M_i / \sum_{i=1}^{n} K_i)$ reported in column 1, expresses <u>industrial</u> machinery imports as a share of the domestic <u>industrial</u> capital stock in each period specified. The ratio is formed after separately summing industrial machinery imports and the industrial capital stock over the reported intervals. In effect it represents a capital stock quality index and as such should indicate whether previously unmeasured qualitative improvements might explain a portion of observed technical progress. Conceptually the choice of the industrial machinery import-capital stock variable implies that the aggregate industrial growth rate is a function of the composition of the capital stock between foreign and domestic durables. Other things equal then, if foreign machinery and embodied more advanced technology than domestic variable, the growth rate should be positively correlated with the industrial machine import-capital stock ratio.

This presumption is clearly not borne out by the evidence. Employing a standardized quinquennial periodization it can be seen that when industrial machine imports comprised eight tenths of one percent of the industrial capital stock 1950-54 the average annual industrial growth rate was 13.6%. In the next quinquennium with the M/K ratio virtually unchanged growth fell 28%, and in all subsequent quinquennia when the M/K ratio rose significantly over the 1950-54 base, the growth rate continued to decline significantly. Essentially the same pattern holds with some incidental variation for the historical periodization as can readily be seen with the aid of the M/K index reported in column 2. Thus instead of the anticipated positive correlation linking the capital stock quality variable and the rate of industrial growth, the actual relationship is more nearly inverse, suggesting that if the null hypothesis is to be rejected it is because the importation of foreign capital <u>retards</u> rather than stimulates economic growth.

Perhaps this counter intuitive result merely reflects our choice of the import variable. Would matters be altered if instead of correlating aggregate industrial machine imports with growth, only Western durable machine imports were considered. Table 2 reveals that the substitution of Western industrial machinery imports for the aggregate measure only intensifies the perserve relationship observed in Table 1. During the period 1955-59 when the industrial growth rate was 9.8%, industrial machine imports from the West constituted 0.12% of the Soviet capital stock or roughly 1.2% of annual industrial investment. By 1970-73 however when the M/K index reached 275 (compared with 128 for the aggregate measure) the industrial growth rate had decreased 39%. Despite a substantially more rapid increase in the contribution of Western durables, compared with total industrial machinery imports, to the qualitative improvement of the Soviet capital stock, the industrial growth rate perversely deteriorated. Clearly then, misspecification of the import variable does not explain the inverse correlation.

A fundamental lesson of Chapter III however where the parameters of abstract technology were estimated subject to the CES specification is that the growth rate is a complex multivariate function which cannot easily be simplified into a univariate output-input relationship. In order to properly observe the correlation between improved capital stock quality and the integument it induces, the obscuring effects of increased input utilization and the elasticity of quantitative factor substitution must be removed. This is easily achieved by respecifying the functional relationship so that the M/K ratio is causally associated with two alternative measures of technical progress. The first is an adjusted version of the Hicks neutral technical progress term, where the secular rate of technical change is adjusted by the residual error of the CES regression on the supposition that

the annual deviation of observed output from the predicted level is the result of fluctuations in the annual rate of technical progress. This supposition is mandated by the fact that the estimated rate of technical progress is intertemporally invariant which if unadjusted would preclude period analysis. Since such a handling of the Hicks parameter is necessarily speculative, the Abramowitz Residual was selected as a second, supplementary measure of technical progress. Taken together the Abramowitz and Hicks series provide a broad impression of the time pattern of technical progress.[26]

Having redefined variables, the null hypothesis can be reassessed with the data provided in Table 3. Some minor changes should be noted before proceeding. First, instead of measuring M/K on an intraperiod basis, the rate of interperiod change is employed as the independent variable. This is done only to emphasize the variation in the industrial machinery import-capital stock ratio, and in no way alters the logic of the previous specification. More substantatively a lagged relationship is introduced into the causal process by stipulating that the rate of adjusted Hicks neutral technical progress depends on the rate of change in the M/K ratio between periods that start and end one year before the interval over which technical progress is defined. This specification reflects the intuitive judgment that imported machinery do not generally enter service at full capacity during the year in which they first arrive. Various alternative weighted lagged schemes were also tried, but gave inferior results to those reported in Table 3. Finally, for the sake of comparison the Abramowitz Residual is left unlagged.

Turning to the results, consider the Hicks series first. Between 1955-60 and 1951-55, using quinquennial periods, adjusted Hicks technical progress increased 36%, while the lagged M/K ratio declined 2%. This repeats the contralogical findings of Tables 1 and 2. The same outcome

Table 3

Soviet Machinery Imports and the Time Profile
Of Hicks Neutral Technical Progress
(Value-Added Classification)
1950-1973

Period Ratios	USSR-WORLD (1) $\sum_{i=1}^{n} M_i / \sum_{i=1}^{n} K_i$	USSR-WEST (2) $\sum_{i=1}^{t} M_i / \sum_{i=1}^{t} K_i$	Period	(3) $\lambda - \varepsilon$	(4) ρ
Quinquennial			1951-55	2.73	4.80
1955-59/1950-54	-2.00		1956-60	3.72	2.49
1960-64/1955-59	38.78	242.00	1961-65	3.53	0.99
1965-69/1960-64	-15.44	-7.02	1966-70	1.13	2.25
1970-73/1965-69	11.30	22.22	1971-73	4.84	2.74
Historical			1951-59	3.05	4.06
1959-63/1950-58	43.55	290.00	1960-64	4.28	1.40
1964-67/1959-63	-18.88	-32.16	1965-68	0.93	1.59
1968-73/1964-67	13.34	70.00	1969-73	3.51	2.69

1. Ratio of machinery imports (M) from all countries, excluding transportation, communication, trade, agriculture and construction durables, to the domestic Soviet capital stock (K) without regard to the sector of origination. The domain of the integrals are determined by the periodization format above.

2. Same as 1, except machinery imports exclusively from the West, (France, Finland, Germany, Italy, Japan, U.K., U.S.), and the initial observation is 1955 instead of 1950.

3. Hicks neutral technical progress minus the error residual from the CES regression. See Table 1, Chapter III.

4. Abramowitz Residual labor share = 0.77. See Table 6, Chapter II, and supplementary Table 6. The periods covered here are 1950-58, 1959-63, 1964-67, 1968-73.

Table 4

Soviet Machinery Imports and the Time Profile
Of Hicks Neutral Technical Progress
(Value of Assemblage Classification)
1950-1973

Period Ratios	USSR-WORLD (1) $\sum_{i=1}^{n} M_i / \sum_{i=1}^{n} K_i$	USSR-WEST (2) $\sum_{i=1}^{t} M_i / \sum_{i=1}^{t} K_i$	Period	(3) $\lambda - \varepsilon$	(4) ρ
<u>Quinquennial</u>			1951-55	2.71	4.53
1955-59/1950-54	-2.00		1956-60	3.56	2.97
1960-64/1955/59	38.78	242.00	1961-65	2.86	0.98
1965-69/1960-64	-15.54	-7.02	1966-70	0.55	2.25
1970-73/1965-69	11.30	22.22	1971-73	4.59	2.72
<u>Historical</u>			1951-59	6.63	3.92
1959-63/1950-58	43.55	290.00	1960-64	3.82	1.36
1964-67/1959-63	-18.88	-32.16	1965-68	0.13	1.61
1968-73/1964-67	13.34	70.00	1969-73	2.67	2.67

1. Ratio of machinery imports (M) from all countries, excluding transportation, communication, trade, agriculture and construction durables, to the domestic Soviet capital stock (K) without regard to the sector of origination. The domain of the integrals are determined by the periodization format above.

2. Same as 1, except machinery imports refer exclusively to the West (France, Finland, Germany, Italy, Japan, U.K., U.S.), and the initial observation is 1955 instead of 1950.

3. Hicks neutral technical progress minus the error residual from the CES regression. See Table 2, Chapter III.

4. Abramowitz Residual labor share = 0.77. See Table 5, Chapter II and Appendix Table A2.1. The periods covered here are 1950-58, 1959-63, 1964-67, 1968-73.

obtains in the following quinquennium where the Hicks rate declines reciprocally with a substantial increase in the capital quality index. Thereafter however a positive correlation pertains, but it would be difficult to argue that this coincidence is non random. Moreover, a glance at Table 4 which replicates Table 3 with the difference that reported residual values are computed on the direct input or "value of assemblage" basis instead of the direct-plus-indirect input or "value added" convention reveals that the random character of these correlations is independent of how the production process is conceptualized. Thus, the evidence suggests that the null hypothesis which stipulates that foreign and domestic capital are statistically indistinguishable cannot be rejected.

Some hope still remains. If the historical periodization recommended by Don Green is adopted, the correlation between adjusted Hicks neutral technical progress computed according to the value added concept (direct-plus-indirect inputs) and the M/K variable is perfect in direction, if not magnitude. Whenever the foreign share of the capital stock rises, Hicks technical increases and vice versa. Despite the ridiculously small sample size one might be tempted to infer that industrial machinery imports do affect the rate of technological progress as theory suggests. Such a conclusion however would be premature unless one is willing, as the author, to accept the superiority of the direct-plus-indirect input classification because as Table 4 indicates measured according to the direct input or value of assemblage convention adjusted Hicks technical progress falls precipitously 1960-64 despite an equally dramatic increase in the M/K ratio. Given the paucity of observations therefore the wisest course is to accept the null hypothesis.

In this regard it should also be mentioned that the small sample size is not really the villain of the piece. Regressions run on all underlying

data points 1950-73 showed a completely random character. The aggregate series presented in Tables 3 and 4 therefore should be viewed as an attempt to eliminate annual random factors which might have obscured the deeper long term causal relationship. The persistence of this random association after the data was adjusted through aggregation should be taken as strong confirmation of null hypothesis, of the hypothesis that Soviet and foreign capital durables are statistically indistinguishable in their effect on Soviet production.

Since there is some reluctance on the part of Soviet specialists to accept the reliability of CES production function estimates, the Abramowitz residuals should be considered before submitting to the siren song of the null hypothesis. As both Tables 3 and 4 demonstrate however the conventional measure of the technology residual is no less randomly associated with the industrial machinery import-capital stock variable than the adjusted Hicks measure. On all counts, the importation of foreign capital goods exhibits no systematic relationship to domestic Soviet industrial technical progress.

As was suggested earlier confirmation of the null hypothesis is tantamount to a judgment on the efficiency of the technology transfer process because in the face of the indubitable superiority of Western technology the separate effects of foreign and domestic capital can only be indistinguishable, if much of the technological advantage embodied in Western durables remains unrealized. Efficiency can be understood however in another sense. On Fisherian premises the Soviets must choose not only between Western and domestic investors' goods, but among alternative lines of investment as well. Should imported industrial machinery and equipment be concentrated in the fuel sector, in chemicals, light industry, construction materials etc.? The answer to this question bears on the effectiveness of aggregate

technology transfer over and above the considerations previously explored because foreign machinery could be allocated to their most profitable intersectoral uses without necessarily contradicting the implications of the null hypothesis. More specifically, Western capital goods could be allocated so that the rate of return over cost were everywhere the same, irrespective of the fact that in conditions of international disequilibrium the rate of return over cost between domestic and foreign industrial machines failed to exhibit the anticipated differential.

Tables 5 and 6 present data necessary for evaluating this second aspect of efficiency. All the variables are familiar; the industrial machinery import-capital stock ratio, Hicks neutral technical progress and the Abramowitz residual. Now however they pertain not to the aggregate industrial relationship but to its sectoral components. This entails some modest respecification. Instead of focusing on interperiod change attention is redirected to intersectoral variations. The Hicks neutral technical change parameter and the Abramowitz residual for the entire postwar period 1950-73 are treated as surrogate measures of the disequilibrium rates of return over cost prevailing in various sectors of the Soviet economy. If the sectoral pattern of capital imports corresponded with the rational investment decision criteria developed by Fisher, then a positive correlation should exist between the intertemporal average industrial machinery import-capital stock ratio and the surrogate measures of the rate of future return over present cost. Specifically the rank ordering of the sectoral values of either the Hicks or the Abramowitz technical progress measure should be positively associated with the average intraperiod values of the sectoral M/K ratios. The higher the rate of return over cost, the greater should be the foreign share of the domestic sectoral capital stock.

Table 5

Postwar Soviet Machinery Imports,
Domestic Capital Growth
And Hicks Neutral Technical Progress
(Value-Added Classification)

Sector	USSR-WORLD (1950-73) (1) $\sum_{i=1}^{24} M_i / \sum_{i=1}^{24} K_i$	USSR-WEST (1955-73) (2) $\sum_{i=1}^{19} M_i / \sum_{i=1}^{19} K_i$	(3) λ	(4) ρ
Fuel	0.75	0.07	1.84	3.05
Metal	0.69	0.10	2.76	2.59
Construction Materials	0.71	0.20	2.97	2.49
Chemical	1.79	0.97	5.73	4.58
Machinery and Equipment	1.19	0.32	2.46	3.40
Light	0.74	0.29	2.11	1.84
Food	0.67	0.09	2.43	1.99
Industry	0.97	0.26	3.08	2.75

1. Ratio of imported machinery (M) from all countries, excluding transport, communication, trade, agriculture and construction durables, to the domestic capital stock (K) of the corresponding sector. The capital stock includes all durables irrespective of sector of origin, including imports. The period covered is 1950-73.

2. Same as 1, except machinery imports refer only to the West (France, Finland, Germany, Italy, Japan, U.K., U.S.), and the period covered is 1955-73.

3. Hicks neutral technical progress. See Table 1, Chapter III.

4. Abramowitz Residual labor share = 0.77. See Table 2, Chapter II.

Table 6

Postwar Soviet Machinery Imports, Domestic Capital Growth And Hicks Neutral Technical Progress (Value of Assemblage Classification)

Sector	USSR-WORLD (1950-73) (1) $\sum_{i=1}^{24} M_i / \sum_{i=1}^{24} K_i$	USSR-WEST (1955-73) (2) $\sum_{i=1}^{19} M_i / \sum_{i=1}^{19} K_i$	(3) λ	(4) ρ
Fuel	1.49	0.09	1.60	3.25
Metal	0.86	0.13	3.55	3.03
Construction Materials	0.99	0.38	2.98	2.83
Chemical	2.70	1.20	3.42	2.61
Machinery and Equipment	1.17	0.31	-	2.87
Light	0.40	0.11	-	2.29
Food	0.62	0.07	2.66	2.59
Industry	0.97	0.26	2.70	2.69

1. Ratio of imported machinery (M) from all countries, excluding transport, communication, trade, agriculture and construction durables, to the domestic capital stock (K) of the corresponding sector. The capital stock includes all durables irrespective of sector of origin, including imports. The period covered is 1950-73.

2. Same as 1, except machinery imports refer only to the West (France, Finland, Germany, Italy, Japan, U.K., U.S.), and the period covered is 1955-73.

3. Hicks neutral technical progress. See Table 2, Chapter III.

4. Abramowitz Residual labor share = 0.77. See Table 2.b, Chapter II.

Once again expectations remain unfulfilled. No matter what pairings are chosen, the correlation between the surrogate indices of rate of return over cost and the foreign share of the domestic capital stock appear entirely random. This is a true characterization whether the M/K variable is narrowly restricted to Western machinery imports or encompasses trade from all nations. It is true for both the Hicks and Abramowitz residual defined either on a direct or direct-plus-indirect input basis. Except for the chemical industry where a high rate of return over cost is consistently associated with a high M/K ratio no economic rationale can be found in the data to explain the observed pattern of Soviet machinery imports. As a consequence, it must be concluded that technology transfer is globally inefficient. Neither in terms of productive impact nor allocational rationality can it be said that the Soviets systematically take advantage of the opportunity costs of trading with the West.

This of course does not mean that the Soviets do not benefit from East-West trade, nor that the technology gap must widen. The demonstrated inefficiency of Soviet technology transfer does suggest however that until the Soviets discover some organizational mechanisms for enhancing the effectiveness of their technology borrowing strategy and practice, the technology gap as well as the differential development levels it implies is unlikely to be closed in any significant way.

VIII. Soviet Technology Transfer: A Summary Assessment

Even before available quantitative evidence was brought to bear on the fundamental issue of the efficiency of technology transfer, it was conjectured that the inadequacies of the Soviet pricing system, the shortcomings of the Typical Method of Soviet investment decision making, and the organizational deficiencies of Soviet central planning would cause achieved gains from

technology transfer to substantially shortfall potential benefits. Now that conjecture, guided by Fisherian theory, has been confirmed quantitatively how do our results affect common perceptions of the technology transfer process both East and West.

For the sake of clarity, the implications of this study can be cast in alternative perspectives. If our argument has been cogent, then the Soviet gain from their substantial efforts at acquiring the benefits of Western technology has been surprisingly modest. In section VI, assuming that a unit of foreign capital augmented technical progress 3% annually compared with 1% for a unit of domestic capital, the maximum Western contribution to Soviet growth was inferred to be 0.6% per annum. This estimate however must now be reduced to 0.3% or two billion dollars because the implied productivity differential of Western durables (3/1) cannot be sustained after the validation of the null hypothesis. If the effects of Western and Soviet capital are indistinguishable then it should be assured that they contribute equally to technical progress net of the contribution imputable to advances in labor skill, that is 1.6% (2.0% - 0.4%). Even this small gain is computed without regard for the opportunity cost of exported Soviet machinery and equipment. Given the validity of the null hypothesis, if the benefits of technology transfer are evaluated in proper Fisherian form, the rate of return over cost is actually unity; that is, the technological gain from trade in the aggregate is zero!

Should this assessment be correct even in a very approximate way, both Western and Soviet analysts have seriously misperceived the economic consequences of technology transfer. For their part, most Western students of Soviet international trade, including the author, have presumed that the Russians have benefited technologically from East-West trade. While our

findings do not necessarily negate this, they do imply that the gains which have accrued are much less than might have been supposed. In fact they are so slight as to preclude the Soviets from closing the technology gap, and thereby drastically shifting the locus of political and economic power adversely against the West as some had sensibly feared.

Judged from the standpoint of our findings Soviet policy makers also must have seriously misperceived the benefits of technology transfer. Table 7, which provides statistical data on postwar trends in the geographical composition of industrial machinery imports, documents the sharp increase in the Western share of imported durables that occurred during the 1960's. Note that contrary to the widespread impression the great leap forward in the Western import share took place in the first quinquennium of the Sixties not the last, but this is a quibble. The evidence conspicuously indicates that against the interests of Comecon the Soviets have chosen to substitute Western for East European capital durables presumably on the supposition that the technological benefits would outweigh the political costs. To the extent that our findings correctly vitiate this implicit supposition, the Soviet strategy for revitalizing their flagging domestic growth must be interpreted as a failure since unrealized gains are balanced against the unnecessary political antagonisms engendered by diverting trade from Comecon to the West.

While it is in no way inconceivable that both Western and Soviet perceptions of the potential benefits of technology transfer may have been in error, as has been repeatedly stressed, the null hypothesis notwithstanding this is not a necessary conclusion. Variable lags in the causal relationship between the importation of Western investors' durables and neutral technical progress, errors in measurement, errors in specification, or random

Table 7

The Geographical Composition
Of Soviet Machinery Imports 1955-1973
(Imports Classified by Sector of Direct Purchase)

USSR-WEST/USSR-WORLD
(Percent)

Period	(1) Industry	(2) Fuel	(3) Metals	(4) Construction Materials	(5) Chemical	(6) Machinery and Equipment	(7) Light	(8) Food
Quinquennial								
1955-60	15.3	8.8	1.6	24.9	38.5	9.9	27.4	10.0
1960-65	26.1	7.5	17.5	44.6	55.4	15.9	27.7	17.4
1965-70	29.8	4.8	6.6	49.2	52.3	36.4	44.5	15.4
1970-73	33.0	8.4	35.2	58.8	50.0	40.4	21.6	11.1
Historical								
1955-58	7.1	4.2	0.2	14.0	10.0	5.4	18.0	8.7
1959-63	26.3	7.4	20.1	41.7	57.4	13.9	30.2	17.4
1964-67	22.1	4.6	6.4	39.6	51.0	17.4	29.7	10.2
1968-73	33.9	7.7	25.4	56.7	51.1	45.0	33.9	12.1
Peak Year								
1969	43.1							
1956		13.9						
1961			42.2					
1974				72.4				
1960					69.6			
1969						78.6		
1968							60.0	
1961								32.5

shocks could all partially explain the ostensible validity of the null hypothesis. Moreover, the mere existence of Western technological alternatives, made real through their importation, could serve as an important catalyst in the development of the indigenous technologies that determine the domestic contribution to neutral technical progress. Taken together these considerations suggest that Western technology might still significantly contribute to Soviet economic development below the threshold of statistical perception. It is important to understand though that this position implies that the impact of Western technology transfers on the Soviet economy cannot be effectively modeled in a dynamic sense. Neither Western nor Soviet analysts are likely to be able to anticipate the economic consequences of specific technology transfers if the causal relationships remain statistically indecipherable. At best Western scholars can guestimate the magnitude of transfer as we have done in section VI, and Soviet planners can mechanically apply the Typical Method without ever really ascertaining true rates of return over cost. However, Western dynamic models which endogenize trade must necessarily be incomplete and the efficiency of real technology transfer selected by Soviet planners subject to the vagaries of blind luck.

Organizational, institutional and decision making reforms aside, the truth of the prevailing situation probably falls somewhere between these alternatives. The Soviets probably do obtain a long run net opportunity cost benefit from technology transfer running perhaps to a few billion dollars annually, a sum which cumulates with time. But the validation of the null hypothesis is also in all likelihood not merely fortuitous. It both reflects the inefficiencies of the Soviet insitutional technology transfer process, and the foregone opportunity for decisively narrowing the technology gap. In sum our analysis suggests that the magnitude of the Soviet achievement in

borrowing technology efficiently and cheaply from the West has been universally and significantly exaggerated.

Notes to Chapter IV

1. Most work on the Soviet technology transfer issue has been descriptive, except for a few notable exceptions where empirical methods guided by theory were applied in order to obtain a consistent perception of the laws governing the technology transfer process. The best summary statement of this work can be bound in Philip Hanson, "The Import of Western Technology" in A. Brown and M. Kaser, editors, The Soviet Union Since the Fall of Khrushchev, Macmillan, 1975, pp. 16-48, which buids on the work of Gomulka, Sutton, Desai and Sylwestrowicz. See A.C. Sutton, Western Technology and Soviet Economic Development, 1945-1965 (Hoover Institution Press, Stanford, 1973); S. Gomulka, "Import of Capital Goods, Technical Change and the Rate of Development: A Generalized Capital-Vintage Model," paper delivered to the Oslo Econometric Meeting (August 1973) and S. Gomulka and J.D. Sylwestrowicz, "Intercountry Embodied Diffusion and the Time Changes in the Factor Productivity Residual," paper presented to the Reisenburg Symposium (1974); P. Desai, "Technical Change, Factor Elasticity of Substitution and Returns to Scale in Branches of Soviet Industry in the Postwar Period," mimeo (1974); Donald Green and Herbert Levine, "Implications of Technology Transfers for the USSR," unpublished manuscript presented at the NATO Colloquium on East-West Technological Cooperation, Brussels, March 17-19, 1976; Donald Green and Marc Jarsulic, "Imported Machinery and Soviet Industrial Production, 1960-1973," SRI Working Paper 39, September 1975.

   Those desiring a descriptive overview of the technology transfer issue in the Soviet context should see John Hardt and George Holliday, "Science, Technology and American Diplomacy, U.S.-Soviet Commercial Relations: The Interplay of Economics, Technology Transfer and Diplomacy," Committee on Foreign Affairs, U.S. House of Representatives (Washington, June 10, 1973). Franklyn D. Holzman, "East-West Trade and Investment Policy Issues: Past and Future," in Soviet Economic Prospects for the Seventies, JEC, (Washington, June 27, 1973). J. Wilczynski, Technology in Comecon, (Praeger, New York, 1974), pp. 260-323. Robert Cambell and Paul Marer, editors, East-West Trade and Technology Transfer, (Bloomington, Indiana, 1974). Edward Hewett, "The Economics of East European Technology Imports from the West," AER, May 1975, pp. 377-82.

   For a more formal, theoretical treatment see Raymond Vernon, "International Investment and International Trade in the Product Cycle," QJE, May 1966, pp. 190-207 and Raymond Vernon, ed., The Technology Factor in International Trade, (NBER, New York, 1970).

   The following pieces also warrant consideration. D. Hawthorne, The Transfer of Technology, (OECD, Paris, 1972). Stanislaw Wasowski, ed. East-West Trade and the Technology Gap, (Praeger, New York, 1969). Samuel N. Bar Zakay, "Policymaking and Technology Transfer: The Need for National Thinking Laboratories," Policy Sciences, Vol. 2, Summer 1971, pp. 213-227. I.S. Koropeckyj, "Technology and the Direction of Soviet Foreign Trade," Rivista Internazionale di Scienze Economiche e Commerciali, December 1973, pp. 1190-1208. Philip L. Swan, "The International Diffusion of an Innovation," Journal of International Economics, September 1973, pp. 61-69. M.V. Posner, "International Trade and Technical Change,"

Oxford Economic Papers, October 1961, pp. 330-7. Kenneth Arrow, "Classificatory Notes on the Production and Transmission of Technical Knowledge," AER, Papers and Proceedings, LIX, May 1969, p. 32. E. Mansfield, "Technical Change and the Rate of Imitation," Econometrica 29, October 1961. Morris Teubal, "Comparative Advantage and Technological Change: The Learning by Doing Case," Journal of International Economics, 3, 1973, pp. 161-78. E. Sheshinski, "Optimal Accumulation with Learning by Doing," in K. Shell, ed., Essays on the Theory of Optimal Economic Growth (MIT Press, Cambridge, Mass., 1967), pp. 31-52.

2. Remember that the marginal productivity of capital according to our CES estimates is extremely low. See Chapter III.

3. Dollars are employed throughout this section on the assumption that real Soviet GNP is 1975 is approximately half that of the U.S. in current U.S. Dollars.

4. Available estimates of the industrial share of GNP vary widely depending on definition and valuation convention. Stanley Cohen, for example, puts the figure at 33.9% on a sector of origin basis in 1964. Bergson's figure for 1959 is 34.4%. Adjusted factor cost input-output data for 1966 based on the sector of delivery approach yields a figure near 42%, assuming services to be 20% to 25% of GNP. See Stanley Cohen, "Soviet Growth Retardation: Trends in Resource Availability and Efficiency," New Directions, Part II-A, JEC, 1966, p. 110 and Steven Rosefielde, The Transformation of the 1966 Soviet Input-Output Table from Producers to Adjusted Factor Cost Values, GE75-TMP-47 (TEMPO, Washington, 1975). Abram Bergson, Soviet Post-War Economic Development (Almqvist & Wiksell, Stockholm, 1974), p. 79. Notice also that the implied rate for technical progress in agriculture, construction and services is 0.8% which seems realistic.

5. John Maynard Keynes, The General Theory of Employment, Interest and Money, (Harbinger, New York, 1964). p. 140.

6. Irving Fisher, The Theory of Interest, (A.M. Kelley, 1970), 150 ff. Also see Jack Hirshleifer, Investment, Interest and Capital, (Prentice-Hall, Englewood Cliffs, N.J.), 1970.

7. Harvey Lapan and Pranab Bardhan, "Localized Technical Progress and Transfer of Technology and Economic Development," Journal of Economic Theory, 6, 1973, pp. 585-595. T.Y. Shen, "Technology Diffusion, Substitution and λ-Efficiency," Econometrica, Vol. 41, #2, March 1973, pp. 263-283.

8. See David Granick, Soviet Introduction of New Technology: A Depiction of the Process, SRI Project 2625, (Stanford Research Institute, Menlo Park, California), 1975.

9. Tipovaia metodika opredeleniia ekonomicheskoi effectivnosti kapital'nykh vlozhenii i novoi tekhniki, Academy of Sciences, Moscow, 1960. A revised version of the Typical Method was published in 1969. See "Standard Methodology for Determining the Economic Effectiveness of Capital Investments, ASTE Bulletin, Vol. 13, #3, Fall 1971, 25-36.

10. See Abram Bergson, The Economics of Soviet Planning, (Yale University Press, New Haven, 1964), Chapter II, and Paul Gregory and Robert Stuart, Soviet Economic Structure and Performance, (Harper and Row, New York, 1974), pp. 220-26.

11. Alexander Gerschenkron, "Russia: Patterns and Problems of Economic Development, 1861-1958," in Economic Backwardness in Historical Perspective, (Belknap, Cambridge, 1966), pp. 119-151. For an opposing view see Arcadius Kahan, "Continuity in Economic Activity and Policy During the Post Petrine Period in Russia," in Michael Cherniavsky, ed., The Structure of Russian History, (Random House, New York, 1970), pp. 191-212.

12. Donald Green and Herbert Levine, "Implications of Technology Transfers for the USSR," unpublished manuscript presented at the NATO Colloquium on East-West Technological Cooperation, Brussels, March 17-19, 1976.

13. See Alexander Gerschenkron, "On the Concept of Continuity in History," in Gerschenkron, Continuity in History, (Belknap, Cambridge, 1968), pp. 11-39. Karl Popper, The Poverty of Historicism, (Harper, New York, 1964).

14. Janos Kornai, Anti-Equilibrium, (North Holland, Amsterdam, 1971), pp. 273-8.

15. This assumes that the ruble-dollar conversion or purchasing power parity ratio for machine tools is 1.1, which corresponds with the values developed from Efirov's data for the 1959 I-O table. Philip Hansen provides a higher ratio $1.74 per ruble which would reduce the 4% figure given in the text, but then to be safe chooses 4% as his upper limit. As the reader understands the computation of purchasing power parity ratios is subject to an embarrassingly wide margin of error. The results presented in this paper therefore should be mentally adjusted according to the reader's judgment on what constitutes the true ruble-dollar parity. See Philip Hansen, "The Import of Western Technology," in A. Brown and M. Kaser, The Soviet Union Since the Fall of Khrushchev (Macmillan, New York, 1975), p. 32.

16. Donald Green and Marc Jarsulic, "Imported Machinery and Soviet Industrial Production, 1960-1973," Soviet Economic Model, SRI, Working Paper No. 39, September 1975, and Donald Green and Herbert Levine, "Implications of Technology Transfers for the USSR," unpublished manuscript presented at the NATO Colloquium on East-West Technological Cooperation, Brussels, March 17-19, 1976, p. 17.

17. Suppose that foreign capital were 15 times more productive than Soviet capital. Then no reasonable value for Soviet capital productivity can be computed. For example, if the foreign share of the total Soviet capital stock were 5% and if the total return to capital from diverse sources were 2%, in line with our previous calculation, then domestic productivity can be computed as

$$\delta = \frac{0.02 - 15/\delta\ (0.05)}{0.95} \quad . \tag{1n}$$

To see this try to substitute values of δ on the right hand side of equation (1n). Trial and error shows that no reasonable solution exists.

18. See Abram Bergson, Soviet Post-War Economic Development, (Almqvist & Wiksell, Stockholm, Sweden, 1974), p. 80. This figure is computed by taking the ratio of US-USSR gross domestic product to gross domestic investment 1960-69.

$$\text{(2n)} \qquad \Pi = \frac{(GDP/GDI)\ US}{(GDP/GDI)\ USSR} = 1.57$$

Notice that equation (2n) probably understates the productivity differential because the denominator includes both Soviet and foreign technologies.

19. For example, if all technical progress were imputed to capital given a negligible return to capital in the narrow sense, then assuming the foreign share of Soviet capital including duplication to be 25%, technical progress generated by foreign capital to be 4%, aggregate technical progress to be 2%, the implied domestic rate is

$$\text{(3n)} \qquad \delta = \frac{.02 - .25\ (.04)}{.75} = .013 \quad ,$$

the productivity ratio is

$$\text{(4n)} \qquad \theta = \frac{4.0}{1.3} = 3.1$$

and the foreign contribution 50% $\left(\frac{0.25\ (0.04)}{0.02}\right)$.

20. See Edward Denison, Why Growth Rates Differ, (Brookings, Washington, 1967), pp. 78-108.

21. Raymond Powell, "Industrial Production" in Abram Bergson and Simon Kuznets, editors, Economic Trends in the Soviet Union, (Harvard U.P., Cambridge, 1963), p. 172.

22. Bergson for one believes that the impact of technology transfer during the Thirties may have been unprecedented compared with U.S. experience. See Abram Bergson, "National Income" in Abram Bergson and Simon Kuznets, editors, Economic Trends in the Soviet Union (Harvard U.P., Cambridge, 1963), p. 34.

23. See footnote 17. The foreign share here is 33% instead of 25%, but the imputed return to advances in labor skill is netted from the 2% annual growth of technical progress. $dG/dt = .33\ (0.0292) + .67\ (0.0095) = 0.016$.

24. $dG/dt = .67\ (.0292) + .33\ (.0095) = .0227$

where G is implied aggregate technical progress. Since actual technical progress was 0.016, the difference is approximately .007.

25. On the superiority of U.S. technology see Philip Hanson, "The Import of Western Technology," in A. Brown and M. Kaser, The Soviet Union Since the Fall of Khrushchev, (Macmillan, New York, 1975), p. 47, note 16.

26. Hanson makes a similar analysis with Desai's estimates of technical progress. See Hanson, Ibid, p. 40.

APPENDIX A

CAN WE QUANTITATIVELY DETERMINE THE INFLUENCE OF TECHNOLOGY TRANSFER ON THE SOVIET ECONOMY?

CAN WE QUANTITATIVELY DETERMINE THE INFLUENCE OF TECHNOLOGY TRANSFER ON THE SOVIET ECONOMY?

Martin L. Weitzman

Massachusetts Institute of Technology

December 2, 1976

This paper is primarily an evaluation of the current state of the production function approach to assessing the significance of technology transfer on Soviet economic growth. My chief source is Steven Rosefield's paper "East-West Trade and Postwar Soviet Economic Growth: A Sectoral Production Function Approach". While I find some parts incomplete, I think there are enough numerical calculations of the right sort in his paper and elsewhere to give a pretty good idea of what can be drawn from this type of study as an input into technology transfer policy analysis.

Unfortunately, I believe the evidence so far is that we cannot determine any influence of technology transfer on Soviet economic growth using existing data. It's too bad, but nothing consistent seems to emerge from the numbers. This is disappointing, but not really very surprising. Despite the massive amount of work that has gone into studying technical change, there are

many fundamental things about it which we cannot seem to pull out of the numbers. For example, to this day we cannot honestly say that aggregate data shows technological change (in the U.S., say) to be more of the embodied than disembodied sort, even though everyone seems to think the embodied type is the more significant.

Although some people would say that all trade with the Soviets benefits them because we are "giving" them something they would not otherwise have, this position is clearly imcomplete. The fact is the Soviets must pay in hard currency for whatever they buy from the West. And to gain that hard currency they must part with saleable commodities like oil, gas, and nonferrous metals. In practice it is very complicated to evaluate the gains from trade. With capital goods, that difficulty is compounded. The gain to the Soviets of importing new technology at a certain cost is the extra output they can produce over and above what they would produce if they spent the same amount on domestically produced capital. The extra output includes any which is due to the diffusion of the new technology throughout the system. In other words, gains to imported technology should show up as increases in factor productivity, technical change, the residual, or whatever else it is called.

Now technical change, despite the huge amount of research devoted to investigating it, is still not very well understood.

And this is a big part of the problem of evaluating technology transfer to the Soviet economy.

Consider, for example, the well known growth retardation of the Soviet economy. This phenomenon is manifest in the Soviet economy as a whole, in industry, and in various industrial sectors. A retardation in output growth has taken place without a slowdown of the same magnitude in the growth of inputs.

In evaluating technical change, economists tend to (somewhat artificially) start by considering combinations of inputs which can be amalgamated to produce the same output level "given the current state of technical knowledge". Thus, inputs are aggregated into a first degree homogeneous index of combined factor inputs. Partly for convenience, the aggregation is traditionally geometric. Over the years output grows faster than the combined inputs index. The ratio of output over inputs is sometimes called an index of total factor productivity. It is a measure of all possible contributions to growth other than what was picked up in the homogeneous of degree one index of combined factor inputs.

Now it is important to emphasize how arbitrary productivity measures can be. They could vary greatly depending on the production function used to aggregate inputs, or on the implicitly presumed form of the technical change (Hicks neutral, by tradition). Sometimes the differences are insignificant relative to the purposes at hand. But for this study that is not the case.

Take the slowdown issue again. When output is divided by a Cobb-Douglas index of inputs, the growth of factor productivity declines dramatically over the years no matter what weights are used. Then output deceleration is implicitly attributed to the stalled-out growth of efficiency, technical change, economies of scale, or whatever else is thought to lie behind the residual.

However, if instead of unity as with the Cobb-Douglas, the elasticity of substitution between capital and labor in the production function index were sufficiently less than one, the Soviet growth record could be explained entirely differently. Then the growth of the residual could be constant, and the slowdown attributable to the ever increasing difficulties of substituting capital for labor in an historical situation where capital has grown rapidly relative to labor.

If econometrically formulated, both of these hypotheses give a reasonably good fit for Soviet industry. And as Desai, Rosefielde, and others have shown, the same dual interpretation is available for branches of industry, so long as intermediate materials are handled in almost any reasonable way.

Now it cannot be stressed enough (because this point is rarely understood) that we cannot really distinquish econometrically between these two hypotheses. Both a Cobb-Douglas production function with appropriately declining growth of technical change and a less than unit elasticity CES with constant growth of tech-

nical change can be made to give <u>about</u> the same error sum of squares in the Soviet case. (If one is slightly better, this might be written off to not getting exactly the right specification on the other.) There is a fundamental trade-off between explaining economic growth in terms of a fixed rate of technological change with an arbitrary production function, or a prescribed production function with arbitrary technological change. And the technical change estimates that emerge from these two stories are very different in the Soviet case. In one story technical change declines sharply; in the other it is constant. So what sense does it make to try to figure out whether technical change residuals correlate over time with (generally miniscule) imports of Western equipment when there is such wide latitude in how the residual might vary? Besides, when such comparisons are made by Rosefielde, nothing systematic emerges. (If the study were redone, it would be nice to have the sector by sector "Abromowitz residuals" weighted by the factor shares of each section, rather than a single uniform weight. Also, it might be important to include materials as inputs into the production function, especially for the food industry.)

Even if machinery imports were weakly correlated with the residual over time, which they are not, would any decent econo-

metrician be seriously prepared to argue causality on that basis? Imports of Western capital go up or down and have a certain time trend of their own. They are a very small percentage of Soviet productive investment. They might happen to weakly correlate with some particular definition of the residual, but this might mean nothing except a common trend, or could be due to some third cause. (For example, a crop failure simultaneously cuts non-agricultural imports and productivity.)

The essential part of the rest of Rosefielde's paper (leaving aside all the talk about methodology) is a sector by sector calculation of (1) non-econometric Abromowitz-Solow residuals, (2) CES production function estimates, and (3) Cobb-Douglas production function estimates. I do not myself see the usefulness of his vertically integrated sectoring, and just disregard it. (He always presents the more traditional numbers as well.) The reasons I do not like it are many, and there is not any purpose to listing them all here given that the more standard alternative is provided.

The CES estimates look roughly like Desai's results. They confirm on a sectoral level the idea that a low elasticity of substitution along with a constant growth rate of the residual can explain well the Soviet pattern. Some of the coefficient estimates look pretty bizarre, and I suppose the thing to do is not take them too seriously. The Cobb-Douglas results with a

constant rate of technological progress look pretty terrible, but there is obviously a bad misspecification here. Presumably the Durban-Watson statistics in this case are awful. I would have liked to have seen the results of a Cobb-Douglas specification with the possibility of decreasing rates of growth of technical change as in my AER piece, but probably the residuals that would emerge are close to the Abromowitz-Solow estimates.

Now when Rosefielde pairs up sectoral residuals of various sorts with his measure of machinary imports, no consistent pattern emerges. One would like to see some explicit statistical rank order testing, and perhaps a few other measures of the significance of imported technology other than what was used. But the clear impression emerges that this road is a dead end. A few numbers stand out as being suggestive, but there is no real statistical power here.

Bluntly speaking, I fear the data and methodological problems may be so overwhelming that we just cannot pull out of this sort of look-and-see approach meaningful answers to questions about the role of technology transfer in influencing Soviet growth. There is a fatal combination of overaggregation, imported technology that is an insignificant fraction of almost all sectors' capital, and a lack of understanding of the basic mechanics of technological change, transfer, and diffusion.

Just as an example, chemicals are relatively high both in terms of the residual's value and in the amount of equipment imported. But, again, who knows anything about cause and effect? The amount of equipment involved is not a high percentage of the total capital. Chemicals are a priority sector in the U.S.S.R. This could mean both high growth rates (in output and the residual) and <u>relatively</u> high imports of Western technology without any causality being implied. Even if these were some weakly significant sectoral correlation between imported technology and technological change (which there is not), it might just mean that the priority sectors are simultaneously pushed into higher growth rates and given more foreign exchange to purchase equipment abroad. That is, capital imports rise hand in hand with domestic efforts to improve production. This seems like a not unreasonable story, although it is not even needed.

If we had a few pure situations of a relatively homogeneous subsector where a large part of the technology had been imported, maybe some meaningful comparisons could be made, and even then maybe not. But look at what we're stuck with. An industry like chemicals is wildly disparite, ranging all the way from the production of ink to synthetic fibers. The capital imported from the West is small relative to what is domestically produced. And it is undoubtedly concentrated in certain specific segments of the chemical industry. Considering all this and the ambiquities of defining the residual, is it any wonder that it is

difficult to make meaningful statistical connections between technological change and imported technology?

Having seen the (negative) results of an informal production function approach, at this stage there would surely be value in pushing ahead with a full specification production function analysis of technology transfer. A start in this direction has already been made by Green and Levine, so that the data are at hand. The ideal statistical procedure would go something like this. A point of departure would be the best production function specification for Soviet industry (or branches) which takes no account of the fact that some capital has been imported. Then this specification is nested in a more general, and at the same time reasonable, specification which takes account of the fact that some of the capital has been imported and allows it to exert its own effect. Probably domestic and imported capital ought to be added together with a weight on imported capital determined by the regression results. The hypothesis that imported capital is more productive than domestic capital is the hypothesis that the weight on imported capital is significantly greater than one. An F-test is performed to determine whether or not the more general specification really gives added explanatory power. If it does, and the coefficient on imported capital indicates it is more important than domestic, there is perhaps the basis for making a case. Even then, one really has to believe in

the specification, particularly in the correctness of the causality, and one has to be reasonably sure that the variable in question isn't picking up the effect of something else, with which it is correlated.

While I fear that a full-fledged statistical treatment is unlikely to yield a marginal productivity of imported capital different from domestic at a level of statistical significance, this approach is still worth trying, especially because the data are now easily available. It and the case study approach seem to be about the only hope we have left at the current time for evaluating the economic impact of technology transfer.

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